HOST RESISTANCE IN BITTERGOURD (*Momordica charantia* L.) TO THE INFESTATION BY THE FRUIT FLY *Dacus cucurbitae* Coq.

2-1

By

V. PADMANABHAN

THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1989

DECLARATION

I hereby declare that this thesis entitled "Host resistance in bittergourd (Momordica charantia L.) to the infestation by the fruit fly Dacus cucurbitae Coq." is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
30-4--1989.

V. PADMANABHAN

CERTIFICATE

Certified that this thesis entitled "Host resistance in bittergourd (*Mömordica charantia* L.) to the infestation by the fruit fly *Dacus cucurbitae* Coq." is a record of research work done independently by Sri.V.Padmanabhan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellanikkara,
30 --4--1989.

Dr.G.Madhavan Nair
(Chairman, Advisory Committee)

Approved by:

Chairman : Dr.G. Madhavan Nair

Members :

Dr.C.C.Abraham

Dr. A.I. Jose

Sri.V.K.G.Unnithan

ACKNOWLEDGEMENTS

I wish to express my profound gratitude and indebtedness to Dr.G.Madhavan Nair, Professor, Department of Agricultural Entomology, College of Agriculture, Vellayani and Chairman of the Advisory Committee, for his sound guidance and constant encouragement throughout the course of the research work and for the invaluable help in the preparation of this thesis.

The author is particularly indebted to Dr.C.C. Abraham, Associate Dean; Dr.A.I.Jose, Professor and Head of the Department of Agrl. Chemistry; & Sri.V.K.G. Unnithan, Associate Professor, College of Horticulture, Vellanikkara, members of the advisory committee, for their critical suggestions and valuable help at every stage of the investigation and preparation of the thesis.

I am grateful to Dr.T.S.Venkitesan, Professor and Head of the Department of Agricultural Entomology, College of Horticulture, for his encouragement and for the facilities provided for the research work.

V. PADMANABHAN

C O N T E N T S

		Page
INTRODUCTION	..	1
REVIEW OF LITERATURE	..	4
MATERIALS AND METHODS	..	20
RESULTS	..	39
DISCUSSION	..	75
SUMMARY	..	94
REFERENCES	..	i - xiv

LIST OF TABLES

No.	Title	Page
1	Details of accessions of bittergourd tested during the summer season for field resistance to *D. cucurbitae*	21
2	Fruit infestation by *D. cucurbitae* on the accessions of bittergourd - summer crop	40
3	Classification of the accessions of bittergourd according to fruit infestation by *D. cucurbitae*	44
4	Fruit infestation by *D. cucurbitae* on the accessions of bittergourd - kharif crop	48
5	The accessions of bittergourd selected for detailed investigations	50
6	Mean percentage values (weekly observations) of fruit infestation in the accessions of bittergourd by *D. cucurbitae* - summer crop	51
7	Mean percentage values (weekly observations) of fruit infestation in the accessions of bittergourd by *D. cucurbitae* - kharif crop	53
8	Orientation of adults of *D. cucurbitae* when exposed to filter paper, impregnated with extracts of fruit of the different accessions of bittergourd	55
9	Ovipositional preference of *D. cucurbitae* when exposed to the cut fruit of the accessions of bittergourd	57

10	Mean larval duration and percentage larval survival of D. cucurbitae reared on the fruit of the accessions of bittergourd	59
11	Mean pupal weight and pupal duration of D. cucurbitae reared on the fruit of the accessions of bittergourd	61
12	Proportion of females of D. cucurbitae when reared on the fruit of bittergourd	63
13	Mean number of eggs laid and mean adult longevity of D. cucurbitae when reared on the fruit of the accessions of bittergourd	65
14	Mean percentage of total sugars, crude protein and sugar/protein ratio in the fruit of the accessions of bittergourd	67
15	Mean percentages of total ash, & silica and ratio of total ash/silica of the fruits of bittergourd accessions	70
16	Mean percentage of total phenolics and moisture content in the accessions of bittergourd fruit	73
17	Correlation coefficients (r) between total sugars, crude protein, total sugars/protein ratio, total ash, silica, ash/silica ratio, total phenolics and moisture per cent in the fruit and the infestation of fruits by D. cucurbitae	74

LIST OF FIGURES

Sl.No.	Description	After page
1	Mean percentage of fruit infestation on the accessions by D. cucurbitae from 9th week after sowing in the summer crop	51
2	Mean percentage of fruit infestation on the accessions by D. cucurbitae from 11th week after sowing in the kharif crop	53
3	Mean number of flies alighted when exposed to filter papers impregnated with extracts of fruit of the different accessions of bittergourd	55
4	Mean number of ovipunctures made when exposed to filter papers impregnated with extracts of fruit of the different accessions of bittergourd	55
5	Mean number of eggs laid by D.cucurbitae in the no choice and multiple choice tests conducted to ascertain the ovipositional preference	57
6	Mean duration of larvae of D.cucurbitae reared on the fruit of the accessions of bittergourd	59
7	Mean percentage of larvae of D.cucurbitae survived and pupated when reared on the fruit of the accessions of bittergourd	59
8	Mean longevity of adult flies when reared on the fruit of accessions of bittergourd	65
9	Mean number of eggs laid when reared on the fruit of accessions of bittergourd	65

Introduction

INTRODUCTION

The fruit fly *Dacus cucurbitae* Coq. (Tephritidae : Diptera) is the most destructive pest of bittergourd (*Momordica charantia* L.). Narayanan and Batra (1960) reported that, in India, this insect infests about twenty seven plants belonging to various families such as Cucurbitaceae, Solanaceae and Leguminaceae. The maggots of this fly cause extensive damage to the fruits. The damaged fruits rot and become unfit for consumption. Lall and Sinha (1959) reported that the extent of damage to the bittergourd crop by the pest may go up to fifty nine per cent.

Being an internal feeder, control of the insect by direct insecticidal application is extremely difficult. The adults being highly elusive, the application of insecticides even at frequent intervals is found to be ineffective. Repeated insecticidal applications may lead to consumer hazards due to insecticide residues in fruits.

Utilisation of host plant resistance for the population management of crop pests is one of the well known approaches in crop protection research. Improved results were obtained by insecticidal application even under low levels of plant resistance (Chalfant and Brett, 1967; Brett and Sullivan, 1970). A low level of resistance may affect the viability of the pests in favour of the activity of natural enemies to the extent that effective control is achieved (Maxwell, 1972). Moderate levels of resistance, coupled with insecticidal application, carefully timed so as to spare the natural enemies of the pest, will indeed be of great help in formulating an effective control method against D. cucurbitae. Identification of the source of resistance by screening bittergourd germplasm and working out the mechanisms of resistance are essential steps to develop genotypes with desired levels of resistance. Identification of bittergourd genotypes with desired levels of resistance will be helpful to formulate integrated pest management practices against the pest. Studies on the spread and peak period of infestation in a cropping season will generate basic information needed to formulate management measures against the pest.

The research work done on host plant resistance in bittergourd to the infestation by D. cucurbitae is scanty. The present studies have, therefore, been taken up to screen different bittergourd genotypes with reference to their susceptibility/resistance to infestation by *D. cucurbitae* and to study the mechanisms of resistance.

Review of Literature

REVIEW OF LITERATURE

General

Painter (1951) defined insect resistance as the relative ability of certain plant variety, due to some specific inherited qualities, to suffer less damage or infestation than other ordinary varieties under the same or comparable environments in the field and classified the resistance mechanism into three aspects, namely, nonpreference, antibiosis and tolerance.

Non-preference denotes the plant characteristics that discourage its use for oviposition, food or shelder. According to Horber (1980) non-preference of a host to insect infestation is a property of the host plant and does not describe the process of negative reactions or total avoidance of the host by the insects during their search for food and sites for oviposition and shelter. Therefore, the term antixenosis is considered as an appropriate substitute for non-preference. Non-preference of crop varieties for feeding and oviposition has been reported by several workers. (Chelliah and Sambandam, 1974 (a); Teli and Dalaya, 1972; Singh and Jotwani, 1980;

Singh and Raman, 1984; Elsy, 1985; Gunathilakaraj and Chelliah, 1985; Ofuya and Akingboghungbe, 1986; Salifu et al., 1988 a).

Antibiosis signifies those preventive, injurious or destructive effects which the host plant exercises on the insect's normal life. Lowered fecundity, reduced growth rate, prolongation of the larval and pupal period, reduced survival, reduced larval and pupal weight, decrease in life span of adults and unfavourable female and male ratios have been reported as manifestations of antibiosis in crops to several pests (Natarajan, 1971; Chelliah and Sambandam, 1974 b; Bindra and Mahal, 1981; Lall and Sukhani, 1982; Bell, 1980; Batra and Sandhu, 1983; Dutta and Saharia, 1984; Durbey and Sarup, 1984; Beach et al., 1985; Suharsono and Talekar, 1985-86; Rufener et al., 1986; Dimock et al., 1986; Ukwangwa and Odebiyi, 1987; Etzel and Mayer, 1986; Sekhan and Sajjan, 1987; Salifu et al., 1988 b).

Tolerance specifies the host plant's ability to sustain a pest population by rapidly repairing or overcoming injury and maintaining its growth and yield.

Comprehensive review on the various aspects of insect resistance in crop plants have been made by several workers (Painter, 1951, 1958; Beck, 1965; Hanover, 1975; Jayaraj, 1976; Panda, 1979 and Pathak and Dale, 1983.)

The work carried out on the biophysical, nutritional and bio-chemical factors responsible for non-preference, antibiosis and tolerance mechanisms of resistance in crop varieties to infestation by major pests in general and with particular reference to D. cucurbitae is reviewed in the following pages.

2. Bio-physical characters

Visual as well as chemical factors are important to evolve orientation response from gravid females. Many aphid species tend to settle on yellow reflecting surfaces (Thorsteinson, 1960). Kennedy ét al. (1961) also observed that in many aphid species, the alighting response was best elicited by yellow orange or green colours, especially yellow colour. According Cartier (1963) pea aphid preferred yellow green plants.

Verma et al. (1981) reported that red leafed varieties of cabbage were less susceptible to the attack by larvae of Pieris brassica, while green leafed varieties were less susceptible to the attack by aphids. According to Renwick (1983), the initial orientation of a phytophagous insect is guided by colour and shape of the host plant.

Plants have developed many defensive mechanisms against phytophagous insects. Plant hairs act as physical barrier keeping smaller insects away from leaf surface. Glandular trichomes and plant glands may exude a sticky substance that entraps and immobilises small insects. They may also contain toxic substances which retard insect growth and delay pupation (Stipanovic, 1983).

According to Thurston and Webster (1966), the aphid Myzus persicae did not survive in Nicotiana gossie, because the toxins exudated by the leaf hairs killed them.

Sambandam and Chelliah (1970) reported that the aphid, Aphis gossypii Glover, could not settle on Solanum mamosum L., as it was beset with closely arranged leaf hairs which prevented it to reach the leaf surface with their feeding stylets.

Panda and Das (1974), in their studies to determine the ovipositional preference of shoot and fruit borer in brinjal varieties, correlated the number of eggs laid with the pubescence of the leaves.

Pubescent cultivars of cotton hindered the movement of the larvae of pink boll worm Pectinophora gossypiella (Smith et al., 1975).

Mehto and Lall (1981) observed that pubescence on the shoots of the brinjal variety, Long purple, conferred resistance against shoot borer Leucinodes orbonalis Guen. The presence of erect hairs on the mid rib & high density of hairs of leaf lamina, mid rib, mid side veins were the factors responsible for conferring resistance to the jassid, Amrasca biguttula biguttula, in brinjal (Bindra and Mahal, 1981).

Bell (1980) reported that the cow-pea varieties with highest number of hairs on the leaf surface were resistant to Aphis craccivora Koch.

Chiang (1984) reported positive correlation between resistance in soyabean to Ophiomyia phaseoli Trayon and O. centrosematis and trichome density.

Hairiness of the leaf lamina and mid rib in the bhindi variety, AE 22, is responsible for resistance to oviposition by cotton jassid, *A. biguttula biguttula* (Uthamaswamy, 1980).

According to Lema (1986), the cassava varieties with pubescent young shoots suffered less damage from *Mononychellus tenajana* and *M. progresivas.*

Kennedy and Sorenson (1985) stated that the glandular trichomes of resistant potato accessions caused extensive mortality to the larvae of the Colarado potato beetle, *Leptinotarsa decemlineata*.

Khan *et al*. (1986) reported that the young leaves of soyabean plants which were densely covered with trichomes were the most resistant to the feeding by noctuid larvae *Trichoplusia ni*. He further stated that the leaves became as susceptible to the attack as the sparsely pubescent leaves, when the trichomes were shaved off from the resistant varieties.

Nair and Abraham (1987) reported that the accessions of brinjal resistant to the infestation of shoot and fruit borer, *L. orbonalis* have higher density of trichome on shoot apex and lower midrib of leaves.

Panda *et al.* (1971) in a field experiment, to evaluate some brinjal varieties for resistance to *L. orbonalis*, found that the resistant varieties had thick compact vascular bundles with lignified cells and had low pith area. The seeds in the fruits were found to be closely arranged.

Teli and Dalaya (1972) reported that in bhindi varieties with hard and tough skinned fruits, the entry of larvae of *Earias vitella* (Fab.) is not easy.

According to Krishnaiah and Vijay (1975), the reasons for lower susceptibility of the two brinjal varieties to the attack of *L. orbonalis* might be due to the hardiness of fruit skin and flesh, a character which is distinctly seen in these varieties.

Subbaratnam (1982) found that the diameter of pith of brinjal varieties had significant correlation with degree of shoot borer damage. Varieties with narrow pith area showed less shoot damage. On the other hand varieties with wider pith area had severe shoot damage. He also with lignified and compact hypodermal sclerenchyma and with broader and compact vascular bundles.

Khaemba (1985) observed that the external pod morphology as well as thickness of pod walls, peduncle length and position of the pod in relation to canopy were associated with the resistance of the cowpea to the attack by *Riptortus dentipens* and *Anoplocnemis curvipens*.

Nair (1983) reported that l[illegible]r pith area, lignified sclerenchymatous hypodermi[illegible]nd compact vascular bundles in the shoots and tight and [illegible]tight calyx in the fruits of brinjal were the factors r[illegible]sible for conferring resistance against the at[illegible]of fruit and shoot borer, *L. orbonalis*.

3. Nutritional and Biochemical facto[illegible]

According to Painter (1958), [illegible]lant must provide not only the nutritional fac[illegible]ired by the insect, but the insect is also depen[illegible]e plant for much more than the nutrients alone. [illegible]ents, physical factors and micro environme[illegible] all play a role in determining the adequacy o[illegible]nt as host for a given insect.

with lignified and compact hypodermal sclerenchyma and with broader and compact vascular bundles.

Khaemba (1985) observed that the external pod morphology as well as thickness of pod walls, peduncle length and position of the pod in relation to canopy were associated with the resistance of the cowpea to the attack by Riptortus dentipens and Anoplocnemis curvipens.

Nair (1983) reported that lower pith area, lignified sclerenchymatous hypodermis and compact vascular bundles in the shoots and tight and semitight calyx in the fruits of brinjal were the factors responsible for conferring resistance against the attack of fruit and shoot borer, L. orbonalis.

3. Nutritional and Biochemical factors

According to Painter (1958), a host plant must provide not only the nutritional factors required by the insect but the insect is also dependent on the plant for much more than the nutrients alone. Chemostimulents, physical factors and micro environmental factors all play a role in determining the adequacy of a given plant as host for a given insect.

Natarajan (1971) reported that brinjal varieties with lower quantities of sugar and starch were less susceptible to the attack by Epilachna vigintioctopunctata.

Sithanantham et al. (1983) reported that the pod walls of the pigeon pea varieties susceptible to the pod fly attack had significantly higher concentration of sugars.

Niraz and Leszezynski (1985) found higher sucrose content in the susceptible varieties of winter wheat against the attack by Sitobion avenae and Rhophalosiphum padi.

Contrary to the above, some workers have reported negative correlation of sugar concentration in plants on the one hand and susceptibility to insect pests on the other. Hebbs et al. (1964) found that higher concentration of sugar is responsible for conferring tolerance in Sequnia, a variety of potato to Empoasca fabae (Harr.).

Thirumurthi (1970), in the case of sorghum varieties resistant to Antherigona varia soccata, detected higher concentration of sugars. Similar results were reported in bhindi varieties resistant to A. biguttula biguttula (Uthamaswamy et al. (1971), Pea varieties resistant to Pea aphid *Bemisia tabaci* (Chhabra *et al*., 1984) and sorghum varieties resistant to stem borer (Khurana and Verma, 1983).

Isahaque and Chaudhuri (1984 a) detected lower percentage of protein in the resistant varieties of brinjal to the infestation by *L. orbonalis*. Similar results were obtained by Nair (1983) also.

According to Panda *et al*. (1975), higher silica content in the rice varieties were responsible for conferring resistance against the attack by stem borer *Scirpophaga incertulas* (Walker). Resistance in the rice varieties to the tissue borer was based on the higher ratio of total ash to silica (Panda, 1976). He substantiated that neither silica nor total ash could reduce the percentage of dead hearts or the rate of larval growth, but it is the proportion of ash to silica which trigger antibiosis mechanism against the borer.

Ukwungwu (1984) found significant correlations between the silica content on the one hand and the damage caused by the larvae of *Chilo zacconius* Bleszynski in the rice plants on the other. Higher the silica content, the less was the damage caused.

Higher silica content on the sheath and collar tissues of maize varieties was responsible for resistance against the attack by European Corn borer *Ostrinia nubilalis* (Rojanaridpiched *et al*., 1984).

Nair (1983) detected significant correlation between the total ash in the fruits of brinjal on the one hand and fruit infestation by *L. orbonalis* on the other.

Injuries to plants induce an increase in the content of toxic phenolic components in the injured cells, the effective toxins being quinones (Gilbert *et al*., 1967).

Natarajan (1971) detected higher concentration of total and orthodihydroxy phenols in varieties of brinjal resistant to the Epilachna beetle. According to Uthamaswamy (1980), the bhindi varieties resistant to the infestation by leaf hopper contained higher concentration of total phenols.

Chiang and Norris (1983) and Chiang (1984) reported that the phenols and tannins were involved in the resistance in undifferentiated tissues and phenols, tannins and lignins were involved in the resistance of differentiated soyabean stem to the attack by *Melanagromyza sojae, Ophiomyia centrosematis* and *O. phaseoli*. The presence of chlorogenic acid, a phenolic component present in the peal of carrot, is responsible for making it resistant to the attack by carrot fly Psila rosae (Cole, 1985). Similar result was reported by Leszezynski (1985) in winter wheat in the case of Sitobion avenae.

Boughdad et al. (1986) in a study on the effects of condensed tannins extracted from the husks of broad beans on the larval development of Callosobruchus maculatus, reported depressed larval development and significant levels of larval mortality.

Singh et al. (1987) found that, in the cultivars of Brassica tournefortii, fewer eggs were laid by the leaf miner Chromatiomyia horticola since it contained larger amounts of total phenols.

4. Studies on D. cucurbitae

Chelliah and Sambandam (1971) and Sambandam and Chelliah (1972) stated that both physical and biochemical factors conferred resistance in Cucumis callosus to the infestation by the fruit fly. The fruit rind of C.callosus, though thinner than the musk melon, was tougher and hard and the levels of sugars & amino acids were lower. Levels of silica, phenolic compounds and minerals were higher in the resistant C. callosus.

Pronounced antibiosis was observed by Chelliah and Sambandam (1974 a & b) in C. callosus to the infestation by D. cucurbitae. The fruit flies reared on the fruits of resistant C. callosus showed low larval survival, prolonged larval period, lower pupal weight and reduced fecundity and longevity of adults. Ovipositional non-preference in C. callosus to fruit fly D. cucurbitae were also studied by them. The non-preference in C. callosus was reported to be due to the lack of ovipositional stimuli and presence of ovipositional inhibitors.

Pal et al. (1983) reported that the accession of muskmelon resistant to the infestation by D. cucurbitae contained lower percentage of total sugars.

Seo et al. (1983) and Seo and Tang (1983) observed that benzyl isothiocynates (BITC) at concentrations of 6.7×10^{-4} mole/1 kg of agar medium act as an inhibitor of oviposition by the adult females of D. cucurbitae. According to them, BITC was naturally produced in green papaya when the tissues were physically damaged during oviposition and larval feeding. They also found that the eggs were more susceptible to BITC than the first instar larvae and between the species D. cucurbitae and C. capitata, the former was found to be more susceptible to BITC.

Singh and Srivastava (1983) reported that an alcohol extract of neem seed oil completely inhibited oviposition by D. cucurbitae.

Doharey and Butani (1986) reported that for D. cucurbitae, bittergourd was found to be the most preferred food, as compared to squash gourd and pumpkin. Maggots developed faster in bittergourd and squash gourd than in pumpkin fruits. Life cycle was also shorter in bittergourd (14.8 days). Pre-oviposition period was highest in bittergourd (11 days) compared to 8.67 days in pumpkin. Number of eggs laid by the fly in pumpkin, squash gourd and bittergourd are 460.66, 347.72 and 296.97 respectively. Longevity of the fly was also studied by the authors. It was shortest in pumpkin (25.5 days) followed by Squash gourd (27.5 days) and bittergourd (30.6 days).

Binomics of the fruit fly D. cucurbitae as a pest of water melon was studied by Shivarkar and

Doharey (1983). Mating took place at night. Pre-oviposition period was 9.53 days and female laid 35 eggs in 2.33 days. Egg period was 26 hrs. Larval period was 6.15 days and pupal period was 6.55 days. Adult life span was 7.7 days for males and 17.13 days for females. There were three larval instars and pupation took place in soil.

Liu and Leey (1987) reported that the pupal duration varied according to the temperature, being 8 days at 30°C and 39 days at 14°C. The duration of pupal stage increased by one day when the pupae had been submerged in water and adult emergence from these pupae was reduced to less than 40 per cent in such cases.

Prokopy and Koyama (1982) reported that, once a potentially suitable host material is located, the females of D. cucurbitae explores it before attempting to oviposit. The flies prefer to oviposit in recent oviposition stings of other females or in breaks in the skin caused by other agents.

Materials and Methods

MATERIALS AND METHODS

The field trial for screening the bittergourd accessions for resistance to fruit fly D. cucurbitae, was conducted at the College of Horticulture, Vellanikkara during the summer season of 1984-85. Based on the results obtained from the screening trial, the accessions were classified into highly susceptible, moderately susceptible and moderately resistant. These were further evaluated during the monsoon season 1985-86.

The details of accessions of bittergourd screened during the summer season are given in the Table 1. The various accessions were obtained from the Department of Olericulture, College of Horticulture, Vellanikkara and also from the sub centre of the National Bureau of Plant Genetic Resources (ICAR) at Vellanikkara.

1. Screening for resistance to D. cucurbitae - Summer crop

A plot of size 60 x 15 m (900 m^2) in the Instructional Farm, Vellanikkara was chosen for the experiment. The land was throughly prepered by digging, breaking clods, levelling and removing weeds. The area

Table 1. Details of accessions of bittergourd tested during the summer season for field resistance to D. cucurbitae

Sl. No.	Accession No.	Cultivar name/ Number	Source
(1)	(2)	(3)	(4)
1	MC 1	MC 1	Dept. of Olericulture, College of Horticulture, Vellanikkara
2	MC 3	MC 3	-do-
3	MC 4	MC 4	-do-
4	MC 21	MC 21	-do-
5	MC 29	MC 29	-do-
6	MC 39	MC 39	-do-
7	MC 49	MC 49	-do-
8	MC 64	MC 64	-do-
9	MC 66	MC 66	-do-
10	MC 69	MC 69	-do-
11	MC 84	MC 84	-do-
12	MC 85	95/82-4	NBPGR, ICAR, Vellanikkara
13	MC 86	60/82-42	-do-
14	MC 87	IC 50527	-do-
15	MC 88	IC 44415	-do-
16	MC 89	IC 44438	-do-
17	MC 90	IC 50526	-do-
18	MC 91	IC 50522	-do-
19	MC 92	122/83-30	-do-
20	MC 93	54/83-11	-do-
21	MC 94	20/82-14	-do-
22	MC 95	IC 44425 B	-do-
23	MC 96	64/82-27 A	-do-

(Contd.)

Table 1 (Contd.)

(1)	(2)	(3)	(4)
24	MC 97	IC 45358	NBPGR, ICAR, Vellanikkara
25	MC 98	IC 33275	-do-
26	MC 99	21/6	-do-
27	MC 100	Mannuthy local	Local
28	MC 101	IC 45342	NBPGR, ICAR, Vellanikkara
29	MC 102	106/82-5	-do-
30	MC 103	IC 44425 A	-do-
31	MC 104	20/83-9	-do-
32	MC 105	111/82-8	-do-
33	MC 106	93/82-89	-do-
34	MC 107	IC 45337	-do-
35	MC 108	IC 44428	-do-
36	MC 109	IC 45326	-do-
37	MC 110	69/82-87 A	-do-
38	MC 111	IC 45339	-do-
39	MC 112	M3/83-16	-do-
40	MC 113	16/83-12	-do-
41	MC 114	Khalidpur	-do-
42	MC 115	20/83-2	-do-
43	MC 116	68/83-16	-do-
44	MC 117	17/83-63	-do-
45	MC 118	IC 44422	-do-
46	MC 119	IC 45345	-do-
47	MC 120	29/7	-do-
48	MC 121	173/83-17	-do-
49	MC 122	65/82-89	-do-
50	MC 123	IC 44420	-do-

(Contd.)

Table 1 (Contd.)

(1)	(2)	(3)	(4)
51	MC 124	54/83-11	NBPGR, ICAR, Vellanikkara
52	MC 125	IC 45338	-do-
53	MC 126	195/81-29	-do-
54	MC 127	107/82-8	-do-
55	MC 128	IC 45357	-do-
56	MC 129	IC 45341	-do-
57	MC 130	IC 50525	-do-
58	MC 131	IC 40526	-do-
59	MC 132	Priya	-do-
60	MC 133	IC 44416	-do-
61	MC 134	28/82-83	-do-
62	MC 135	M/83-82	-do-
63	MC 136	2/86-87	-do-
64	MC 137	M3/83-29	-do-
65	MC 138	125/82-83	-do-
66	MC 139	125/82-21	-do-

was divided into three blocks, each of size 20 x 15 m, by forming marginal bunds. Pits of the size 60 cm in diameter and 45 cm in depth were taken at a spacing of 2 x 1.5 m. Farm yard manure at the rate of 10 kg, urea at four grams, superphosphate at eight grams and muriate of potash at three grams, per pit were applied. Four to five seeds were sown in each pit, two days after the application of fertilizers and watering was given at regular intervals. After germination, three healthy plants were retained in each pit and rest of the plants were removed. The plants were trailed on standards. Branches cut from trees which were about seven feet in length and about four cm in thickness and with numerous side shoots were used as standards.

Weeding and earthing up were done thrice on 30th, 45th and 60th days after sowing the seeds. The crop was top dressed with urea at the rate of three grams per pit at the time of each earthing up.

The bittergourd accession MC 132, a known susceptible variety, was raised all along the border of the experimental field, two weeks in advance of raising the main crop, to ensure natural build-up of field populations of fruit flies to provide immediate source of infestation for the experimental crop.

The experiment was laid in R.B.D. with 66 treatments replicated three times. Three plants in one pit formed the experimental unit.

The relative susceptibility of the accessions of bittergourd to infestation by *D. cucurbitae* was recorded in terms of fruit infestation. The observations on fruit damage were recorded at weekly intervals. The fruit harvested from each pit were first sorted out into infested and healthy ones.

2. Classification of accessions of bittergourd on the basis of infestation by *D. cucurbitae*

The data on the fruit damage of the different accessions obtained from the screening trial were subjecte to analysis of variance and the accessions were then rated according to the following scales (Table 2 and Table 3).

Resistant	-	Less than 10 per cent fruit damage
Moderately resistant	-	Between 10 - 20 per cent fruit damage
Moderately susceptible	-	Between 20 - 30 per cent fruit damage
Highly susceptible	-	Above 30 per cent fruit damage

3. Screening for resistance to Dacus cucurbitae - Kharif crop

The accessions of bittergourd having fruit damage up to twenty five per cent, recorded in the summer trial, were again screened for resistance to D. cucurbitae in a field trial conducted during the Kharif season of 1985-86 using MC 132 as the check variety. There were twenty one accessions in this trial. The details of the accessions selected for the kharif trial are given in the Table 4. In this trial, instead of pits, mounds of size 45 cm in diameter and 15 cm in height were taken. Three plants were retained in each mound. The experiment was laid in RBD with three replications. The procedure adopted for recording the observations and analysing the data in the summer crop was followed in the kharif crop also.

Out of the twenty one accessions tested during the kharif season in the field, six were selected for detailed studies in the laboratory. Three accessions belonging to the moderately resistant group, two belonging to the moderately susceptible group and one belonging to the highly susceptible group were selected for detailed studies (Table 5). No accession was found to be resistant in the field trials.

4. Rearing of D. cucurbitae in the laboratory

The stock culture of D. cucurbitae required for the experiment was maintained following the method developed by Chelliah and Sambandam (1974) with suitable modifications. Glass jars of size 30 cm long, 30 cm wide and 30 cm high were used for this purpose. The top of the jars were closely covered with polynet frames.

The fruit of bittergourd accession MC 132 were used for the mass rearing the fruit fly D. cucurbitae. The infested fruit were collected from the field and placed inside the rearing jars with a layer of clean moist sand spread at the bottom. The maggots which are ready for pupation came out of the fruit and entered the moist sand and then pupated. The pupae were collected and kept in rearing jars for the emergence of adults.

The adult flies started emerging from seventh day onwards. Most of the flies emerged on the seventh day itself. Cotton swab soaked in 15 per cent honey solution in distilled water was kept inside the rearing jars as food for the emerging flies. For laying eggs, fresh tender bittergourd fruit were kept in the glass jars after the pre-oviposition period of eleven days.

The stalk end of the fruit were covered with cotton swab soaked in water so as to prevent the quick drying of the fruit. The fruit on which the flies oviposited were transferred and kept in glass troughs.

After an egg period of twenty four hours, the first instar larvae started emerging. The maggots were extracted carefully on the third day after emergence. They were let into fresh tender bittergourd fruit at the rate of four maggots per fruit, after making a small hole of 1 mm diameter for the easy entry of the maggots. The fruit thus inoculated were kept in separate glass troughs covered with muslin cloth. Cotton swabs soaked in water were kept at the stalk end of the fruit, so as to prevent quick drying of the fruit. On the sixth day the fruit were transferred to glass jars containing clean moist sand. Most of the maggots pupated on the seventh day and a very few on the eighth day. The pupae were collected and transferred into rearing jars.

5. Orientation of fruit flies towards fruit extracts of different accessions of bittergourd

Whatman No.1 filter papers were impregnated with fruit extracts of the accessions of bittergourd. The fruit extracts were prepared by grinding fresh fruits in an electric blender and the juice was extracted by hand squeezing of the pulp. The impregnation was done by applying the fruit extract drop by drop on a filter paper till saturation. The margins of the filter papers were covered with cheese cloth. Six impregnated filter papers, one from each accession, were arranged at the bottom of a large trough at equal spacing. Five gravid female flies were released inside the glass trough which was then covered with muslin cloth. The number of flies resting on each of the filter paper were recorded at an interval of ten minutes for sixty minutes. Number of ovipunctures made on the filter papers were also counted and recorded. The experiment was replicated six times.

6. Ovipositional preference

The method adopted by Chelliah and Sambandam (1974) with suitable modifications was used for determining the ovipositional preference of adult females of D. cucurbitae on the selected accessions of bittergourd.

Multiple choice test

Large sized troughs of 30 cm in diameter and 15 cm in height were used for this test. Top portion of the troughs were covered with muslin cloth. Fruits of the six accessions of bittergourd were cut into pieces of size 2 x 4 cm and a cut piece of each of the six accessions was arranged at the bottom of the trough. Two gravid females flies were released in the trough and covered with muslin cloth. The cut fruit were rearranged at random on the second day. On the third day the cut fruit were taken out and the number of maggots in each fruit piece was counted and the data statistically analysed. The experiment was replicated six times.

No choice test

Glass troughs of size 15 cm in diameter and 7.5 cm in height were used for this experiment.

A bittergourd fruit was cut into pieces of size 2 x 4 cm and a single piece was placed inside a trough. Six jars each with a piece of fruit of each accession formed a replication. Two gravid female flies were released in each trough. After three days, the cut fruits were taken out and the number of maggots in the cut fruits was counted and the data statistically analysed. This experiment was repeated six times.

7. Larval period and larval survival

Larval period was determined by recording the duration from hatching to pupation. Small cut bits of bittergourd fruit measuring 2 x 4 cm were placed inside a glass trough. Two gravid female flies were released in the glass trough containing the cut fruit for oviposition. Maggots started emerging after twenty four hours. Newly hatched maggots were extracted very carefully with a fine camel brush and four numbers of maggots were released on the fruit of each accession after making a small hole of 1 mm diameter on each fruit for easy entry of the maggot. The inoculated fruit placed inside separate glass troughs with moist sand and the troughs were covered with muslin cloth. The maggots were transferred to fresh fruit as and when necessary. The duration of the larval period and the number of larvae pupated in each accession were recorded and the percentage of survival were worked out. The experiment was carried out in completely randomised design with six replications.

8. Pupal weight and pupal period

The weight of the pupae collected from different accessions were recorded using a Sartorius (model 2474) electric balance and transferred to glass vials of size

7.5 x 2.5 cm with moist sand at the bottom for adult emergence. The duration of pupal period was recorded. The adult flies emerged were sexed and the sex ratio worked out.

9. Fecundity

A pair of gravid female flies reared from each of the accession were released in glass jars containing sliced bittergourd fruit of the same accession for oviposition. Cotton swab soaked in 15 per cent honey solution in distilled water was kept inside the rearing jars as food for the flies. The jars were covered with muslin cloth. The number of eggs laid on each accession were ascertained by counting the number of maggots developed in each cut piece of bittergourd. Freshly cut fruit were provided periodically for oviposition. The experiment was continued up to 30 days. The experiment was laid out in completely randomised design with six replications.

10. Longevity of flies

Longevity of flies reared from different accessions were ascertained by keeping the newly emerged flies on a diet of 15 per cent honey solution in glass jars. The duration from emergence to death of the flies were recorded. The experiment was replicated six times for each accessions.

11. Preparations of dry samples of fruit for various chemical analysis

The samples of fruit of the six accessions used for various laboratory experiments, namely, MC 103, MC 104, MC 114, MC 97, MC 123 and MC 132 were analysed to determine the levels of moisture, total ash, silica, total sugars, crude protein and total phenolics.

11.1 Moisture

Two hundred grams of fresh tender fruit from each of the six accessions were chopped separately and dried in the sun for two days. The samples were then taken in paper bags and were placed inside an electric oven at 85°C for 48 hours. The samples were then taken out cooled and weighed. The samples were once again kept in the oven for six hours and weighed after cooling. The process was repeated until the two consecutive weights agreed. Then the moisture percentage was worked out from six samples from each accessions and mean values worked out.

11.2 Preparation of dry samples for various chemical analysis

Dry samples of fruit were used for the estimation of various constituents except total phenols for which fresh samples were used. The fruit material for the preparation of samples were taken from the monsoon crop. Fresh tender fruit of different accessions were chopped into small pieces separately and dried in the sun for two days. The samples were then taken in paper bags and placed inside an electric oven at 80°C for 48 hours. The samples were then taken out from the electric oven and ground in a grinding mill. The powdered samples were then stored in airtight plastic bottles. Six separate samples were prepared for each accession.

11.3 Total ash

Five grams of the dried sample of the fruit was weighed in a chemical balance and transferred to a dry silica crucible and weight of the sample plus crucible was taken. The crucible was then heated for one hour and transferred to a muffle furnace and kept at 550°C for six hours till the white ash was obtained. The crucible was cooled in desiccator and weighed. The total ash content was estimated from the difference in weight and percentage worked out.

11.4 Silica

Silica was estimated by gravimetric method from the ash obtained by igniting the sample in muffle furnace after the estimation of total ash.

Thirty ml of 1+1 Hydrochloric acid was added to the silica crucible containing ash. The crucible was covered with a watch glass and boiled for 30 minutes, using a hot plate. The watch glass was removed and rinsed with little water and filtered through Whatman No.40 filter paper. Washing was continued until the washings were free of chlorides. The filter paper along with residue was then dried up and incinerated in a weighed silica crucible and ignited in a muffle furnace for two hours. The crucible was cooled in a desiccator and weighed. The silica was estimated from the difference in weights of crucible.

11.5 Total sugars

Two grams of the dry sample was transferred into a 100 ml volumetric flask. About 10 ml of dilute hydrochloric acid 1+1 was then added and the mixture then kept at room temperature for twenty four hours.

The sample was neutralised with IN NaOH using phenolpthalien as the indicator and the volume was made up with distilled water and filtered. 5 ml each of Fehlings solution A and Fehlings solution B were pipetted out in a 250 ml conical flask and about 50 ml of distilled water was added. The contents were boiled and while boiling the sample, extract taken in burette was titrated against Fehlings solution till the blue colour disappeared. Then about 0.5 ml of methylene blue indicator was added and continued boiling till the brick red colour was obtained. From the tiration value the percentage of sugar content was calculated.

11.6 Crude protein

One gram of the powdered fruit sample was transferred into a Kjeldahl's digestion flask to which was added 1 gm of copper sulphate 10 g of potassium sulphate and 25 ml of concentrated sulphuric acid. The contents were heated on a burner gently and then strongly till a light blue coloured solution was obtained. Heating was continued for 30 minutes and then cooled.

30 ml of water was added and stirred carefully to prevent caking.

The contents in the digestion flask was transferred into a Kjeldahl distillation flask and washed thoroughly. A few pieces of granulated zinc were added. 200 ml of 40 per cent sodium hydroxide was poured, so that the contents became alkaline as indicated by the litmus paper. The distillate was collected into a 200 ml conical flask containing a known excess of sulphuric acid. The excess acid was found by back titrating with sodium hydroxide. Crude protein was obtained by multiplying the nitrogen per cent by 6.25.

11.7 Total phenols

Total phenols was determined by colorimetric method (Ranganna, 1978). One gm sample of fresh bittergourd fruit was weighed and the distilled water extract was prepared. The extracts were transferred to 100 ml volumetric flasks and the volume made up. Colour was developed by Folin Dennis reagent and read in a Spectronic 20 spectrophotometer, at 760 nm against experimental blanks. Standards were prepared from tannic acid dissolved in distilled water.

12. Design of experiments

Randomised Block Design was adopted for the field screening experiments. Completely Randomised design was adopted for other laboratory experiments. The biochemical constitution of the fruits were compared based on mean percentage values from pooled analysis of samples and simple correlation coefficients were worked out.

Results

RESULTS

Screening trial - Summer crop

The mean percentage values of fruit infestations by D. cucurbitae in different accessions of bittergourd as estimated on the basis of the number of infested fruit are presented in Table 2. Significant differences were detected among the accessions with reference to the levels of infestation by the fruit fly.

The accessions MC 132, MC 128, MC 126, and MC 127 suffered relatively heavier infestation, the range in the percentage of fruit infestation in these accessions being from 71.716 to 74.266. Between them there was no significant variation. The accessions MC 131, MC 49, MC 3, MC 130, MC 101, MC 118 and MC 109 showed mean percentage values of infestation between 58.250 and 60.583; the accessions MC 94, MC 1, MC 117, MC 102, MC 110 and MC 21 between 49.616 and 53.450 and the accessions MC 93, MC 29, MC 125, MC 138, MC 139, MC 100, MC 99, MC 111 and MC 108 between 42.033 and 45.183. The accessions MC 92, MC 124, MC 121 showed

Table 2. Fruit infestation by D. cucurbitae on the accessions of bittergourd - Summer crop

Accessions of bitter-gourd	Mean per cent of fruit infestation	Accessions of bittergourd	Mean per cent of fruit infestation
(1)	(2)	(1)	(2)
MC 103	10.866	MC 90	24.933
MC 115	11.783	MC 39	25.183
MC 116	12.900	MC 4	26.083
MC 104	14.683	MC 106	27.316
MC 88	16.600	MC 91	28.283
MC 112	17.250	MC 105	29.316
MC 114	18.350	MC 85	29.383
MC 122	18.833	MC 121	30.833
MC 96	20.083	MC 124	31.700
MC 95	20.233	MC 92	33.983
MC 87	20.683	MC 133	36.250
MC 97	21.016	MC 134	36.433
MC 98	21.050	MC 84	38.283
MC 89	21.950	MC 120	38.500
MC 86	23.233	MC 137	39.616
MC 113	23.750	MC 108	42.033
MC 123	23.933	MC 111	42.616
MC 64	24.100	MC 99	43.283
MC 107	24.766	MC 100	44.133

(Contd.)

Table 2 (Contd.)

(1)	(2)	(1)	(2)
MC 139	44.166	MC 3	60.183
MC 138	44.300	MC 49	60.283
MC 125	44.616	MC 131	60.583
MC 29	44.916	MC 135	64.350
MC 93	45.183	MC 129	68.383
MC 119	46.533	MC 66	68.966
MC 136	49.083	MC 69	70.216
MC 21	49.616	MC 127	71.716
MC 110	50.050	MC 126	72.716
MC 102	51.683	MC 128	73.683
MC 117	52.050	MC 132	74.266
MC 1	52.283		
MC 94	53.450		
MC 109	58.250		
MC 118	58.450		
MC 101	59.450		
MC 130	59.950		
CD (0.05)	3.863		

infestation percentage values ranging from 30.833 and 33.983. The accessions in each of the above mentioned clusters did not vary significantly among them.

The accessions MC 4, MC 39, MC 90, MC 107, MC 64, MC 123, MC 113, and MC 86 showed infestation levels between 23.233 and 26.083 per cent and these accessions did not differ significantly between them. The accessions MC 89, MC 98, MC 97, MC 87, MC 95 and MC 96 showed infestation between 20.083 and 21.950. The mean percentage infestations on the accessions MC 122, MC 114, MC 112, MC 88, MC 104, MC 116, MC 115 and MC 103 ranged between 10.866 and 18.833.

However, the accessions MC 96, MC 113, MC 123, MC 90, MC 106, MC 85 showed moderate susceptibility and their percentage infestation of fruit ranged from 20.083 to 29.383.

The lowest levels of infestation were recorded in the accessions MC 103, MC 115 and MC 116 the values being 10.866, 11.783 and 12.900 respectively which differed significantly from all the other accessions, except MC 104.

None of the tested accessions showed infestation levels, below ten per cent.

2. Classification of accessions on the basis of the intensities of fruit infestation

Based on the intensity of fruit infestation in the summer crop, the accessions were classified into four groups, namely, highly susceptible, moderately susceptible, moderately resistant and resistant, following the method given under item (2) in materials and methods (Table 3).

Following the above norms, the accessions MC 132, MC 128, MC 126, MC 127, MC 69, MC 66, MC 129, MC 135, MC 131, MC 49, MC 3, MC 130, MC 101, MC 118, MC 109, MC 94, MC 1, MC 117, MC 102, MC 110, MC 21, MC 136, MC 119, MC 93, MC 29, MC 125, MC 138, MC 139, MC 100, MC 99, MC 111, MC 108, MC 137, MC 120, MC 84, MC 134, MC 133, MC 92, MC 124 and MC 121 were classified as highly susceptible, the accessions MC 85, MC 105, MC 91, MC 106, MC 4, MC 39, MC 90, MC 107, MC 64, MC 123, MC 113, MC 86, MC 89, MC 98, MC 97, MC 87, MC 95 and MC 96 were classified as moderately susceptible and the accessions MC 122, MC 114, MC 112, MC 88, MC 104, MC 116, MC 115 and MC 103

Table 3. Classification of the accessions of bittergourd according to fruit infestation by <u>D. cucurbitae</u>

Susceptibility/ resistance rating	Accessions	Mean per cent damage of fruits
(1)	(2)	(3)
Highly susceptible (Above 30 per cent fruit damage)	MC 132	74.266
	MC 128	73.683
	MC 126	72.716
	MC 127	71.716
	MC 69	70.216
	MC 66	68.966
	MC 129	68.383
	MC 135	64.350
	MC 131	60.583
	MC 49	60.283
	MC 3	60.183
	MC 130	59.950
	MC 101	59.450
	MC 118	58.450
	MC 109	58.250
	MC 94	53.450
	MC 1	52.283
	MC 117	52.050
	MC 102	51.783
	MC 110	50.050
	MC 21	49.616
	MC 136	49.083
	MC 119	46.533
	MC 93	45.183

(Contd.)

Table 3 (Contd.)

(1)	(2)	(3)
	MC 29	44.916
	MC 125	44.416
	MC 138	44.300
	MC 139	44.166
	MC 100	44.133
	MC 99	43.283
	MC 111	42.616
	MC 108	42.033
	MC 137	39.616
	MC 120	38.500
	MC 84	38.283
	MC 134	36.433
	MC 133	36.250
	MC 92	33.983
	MC 124	31.700
	MC 121	30.833
Moderately susceptible (Fruit damage 20-30 per cent)	MC 85	29.383
	MC 105	29.316
	MC 91	28.283
	MC 106	27.316
	MC 4	26.083
	MC 39	25.183
	MC 90	24.833
	MC 107	24.766
	MC 64	24.100
	MC 123	23.933
	MC 113	23.750
	MC 86	23.233
	MC 89	21.950

(Contd.)

Table 3 (Contd.)

(1)	(2)	(3)
	MC 98	21.050
	MC 97	21.016
	MC 87	20.683
	MC 95	20.233
	MC 96	20.083
Moderately resistant (fruit damage 10-20 per cent)	MC 122	18.883
	MC 114	18.350
	MC 112	17.250
	MC 88	16.600
	MC 104	14.683
	MC 116	12.900
	MC 115	11.783
	MC 103	10.866
CD (0.05)		3.863

were classified as moderately resistant in respect of fruit infestation. None of the tested accessions recorded less than ten per cent fruit infestation and hence no accession could be rated as resistant.

3. Screening trial - Monsoon crop

Twenty bittergourd accessions which showed fruit damage intensities up to twenty five per cent in the summer season trial along with a highly susceptible accession MC 132 were further field screened during the following monsoon season. The mean per cent values of fruit damage in the monsoon crop are given in Table 4. All the bittergourd accessions except MC 132 showed higher levels of fruit damage in the monsoon crop as compared to the summer crop.

The mean percentage of fruit damage ranged from 11.683 to 27.366 in the accessions tested, except in MC 132 which suffered the maximum fruit infestation of 71.733 per cent. The accession MC 103, and MC 115 showed significantly lower levels of infestation than other accessions except MC 116. The accessions MC 113, MC 86, MC 123 and MC 64 had infestation levels between 26.183 to 27.366 per cent. The other accessions showed intermediate levels of infestation.

Table 4. Fruit infestation by D. cucurbitae on the accessions of bittergourd - Kharif crop

Accession Number	Cultiver name/ number	Mean percentage of fruit damage
MC 103	IC 44425 A	11.683
MC 115	20/83-2	13.083
MC 116	68/83-16	14.016
MC 104	20/83-9	15.183
MC 112	M3/86-16	16.016
MC 88	IC 44415	16.916
MC 114	Khalidpur	19.350
MC 122	65/82-29	20.383
MC 96	64/82-87 A	20.650
MC 87	IC 50527	21.500
MC 89	IC 44438	21.816
MC 95	IC 44425 B	22.816
MC 97	IC 45358	23.216
MC 98	IC 33275	23.816
MC 90	IC 50526	24.300
MC 107	IC 45337	24.883
MC 113	16/83-12	26.183
MC 86	60/82-42	26.386
MC 123	IC 44420	26.883
MC 64	MC 64	27.366
MC 132	Priya	71.733
C.D. (0.05)		1.910

4. Selection of accessions for detailed studies

Out of twenty one accessions of bittergourd screened during the monsoon season, six accessions were further selected for detailed studies. Thus three accessions (MC 103, MC 104, MC 114) from the moderately resistant group, two (MC 97 and MC 123) from the moderately susceptible group and the highly susceptible accession MC 132 were selected for detailed investigations (Table 5).

5. Fruit infestation in relation to the age of the plants

The mean percentage of fruit infestation by <u>D. cucurbitae</u> worked out from observations recorded at weekly intervals commencing from the 9th week after sowing in the summer crop and from 12th week after sowing in the monsoon crop are given in the Table 6 and 7 and depicted in the Fig. 1 and 2.

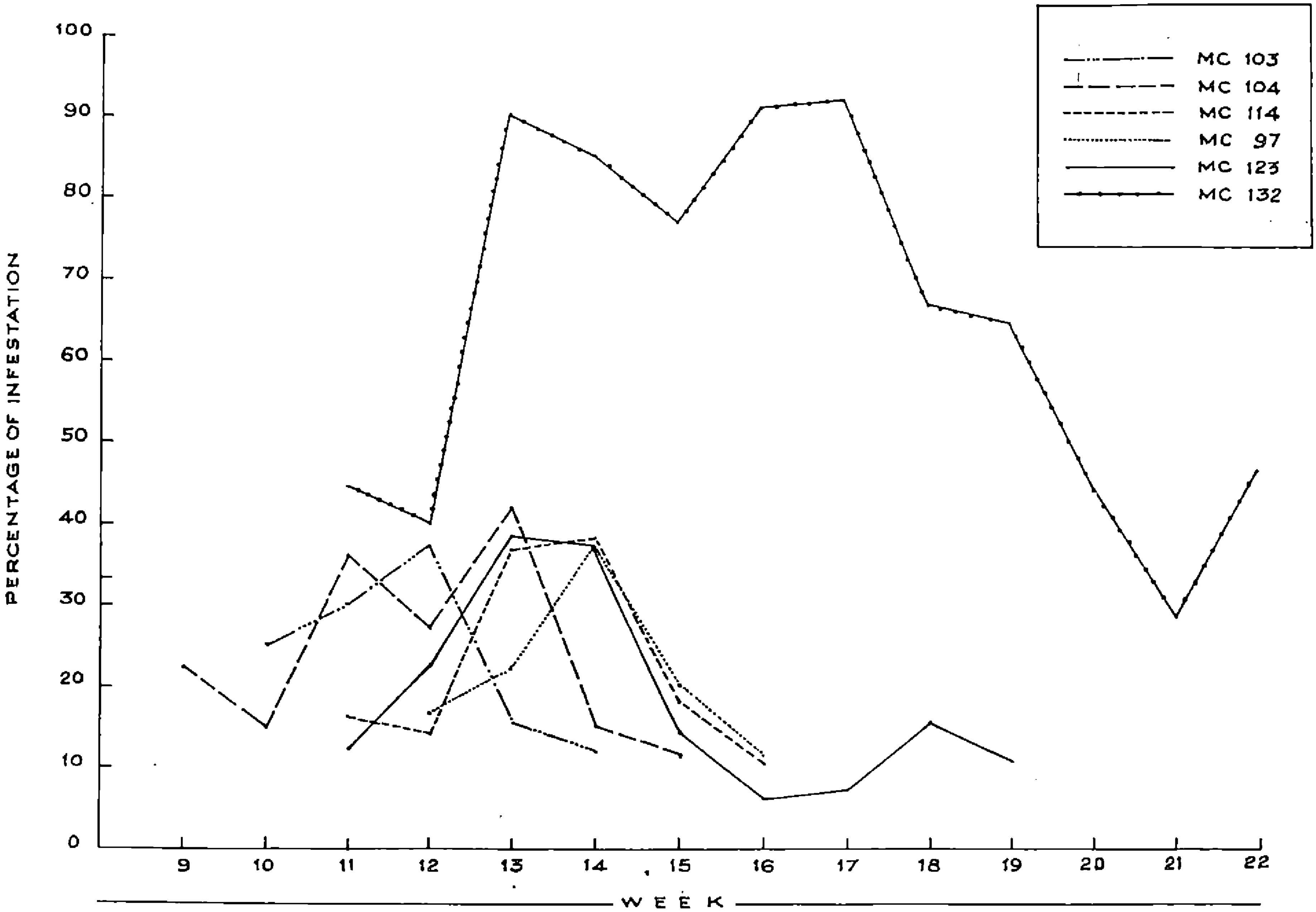
The initial record of fruit infestation was in MC 104 which started in the ninth week after seeding, whereas in MC 103, it was in the tenth week. In MC 114, MC 123, and MC 132, the infestations commenced in the eleventh week after seeding. In MC 97 the infestation

Table 5. The accessions of bittergourd selected for detailed investigations

Susceptibility/ resistance rating	Accessions	Cultivar number/ name	Mean percentage of fruit damage	
			Summer crop	Monsoon crop
Moderately resistant	MC 103	44425 A	10.866	11.683
-Do-	MC 104	20/83-9	14.683	15.183
-Do-	MC 114	Khalidpur	18.350	19.350
Moderately susceptible	MC 97	IC 45358	21.016	23.216
-Do-	MC 123	IC 44420	23.933	26.883
Highly susceptible	MC 132	Priya	74.266	71.733

Table 6. Mean percentage values (weekly observations) on fruit infestation in the accessions of bittergourd by *D. cucurbitae* from 9th week after sowing in the summer crop

Accessions	Week														
	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22nd	23rd	24th
MC 103	-	25.00	30.00	37.50	15.50	12.00	-	-	-	-	-	-	-	-	-	-
MC 104	22.50	14.85	36.45	27.27	42.85	15.50	11.50	-	-	-	-	-	-	-	-	-
MC 114	-	-	16.75	14.28	37.50	38.60	16.75	10.50	-	-	-	-	-	-	-	-
MC 97	-	-	-	16.65	22.35	37.50	20.00	11.50	-	-	-	-	-	-	-	-
MC 123	-	-	12.50	22.50	38.50	37.50	14.50	9.50	10.50	15.40	10.60	-	-	-	-	-
MC 132	-	-	44.50	40.00	90.00	85.75	76.90	90.80	91.66	66.75	63.90	43.75	28.35	45.75	-	-



MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
100
90
80
70
60
50
40
30
20
10
0
PERCENTAGE OF INFESTATION
9
10
11
12
13
14
15
16
17
18
19
20
21
22
WEEK

started as late as in the 12th week. The peak period of infestation in the accessions MC 103, MC 104, MC 114, MC 97, MC 123 and MC 132 are 12th, 13th, 14th, 14th, 13th and 17th week respectively.

The infestation periods in the summer season was the shortest in MC 103 and longest in MC 132 and the infestations ended in the 14th and 22nd weeks respectively. The duration of infestation in MC 104 was from 9th week to 15th week, in MC 114 from 11th week to 16th week, in MC 97 from 12th week to 16th week and in MC 123 from 11th week to 19th week.

During the monsoon season also (Table 7), the spread of infestation was almost similar to that in the summer season. The shortest period of infestation was found in MC 103 and MC 104 i.e. from 12th to 17th week, whereas, the longest spread of infestation was in MC 132 i.e. from 12th to 22nd week. Other accessions showed intermediate levels of duration.

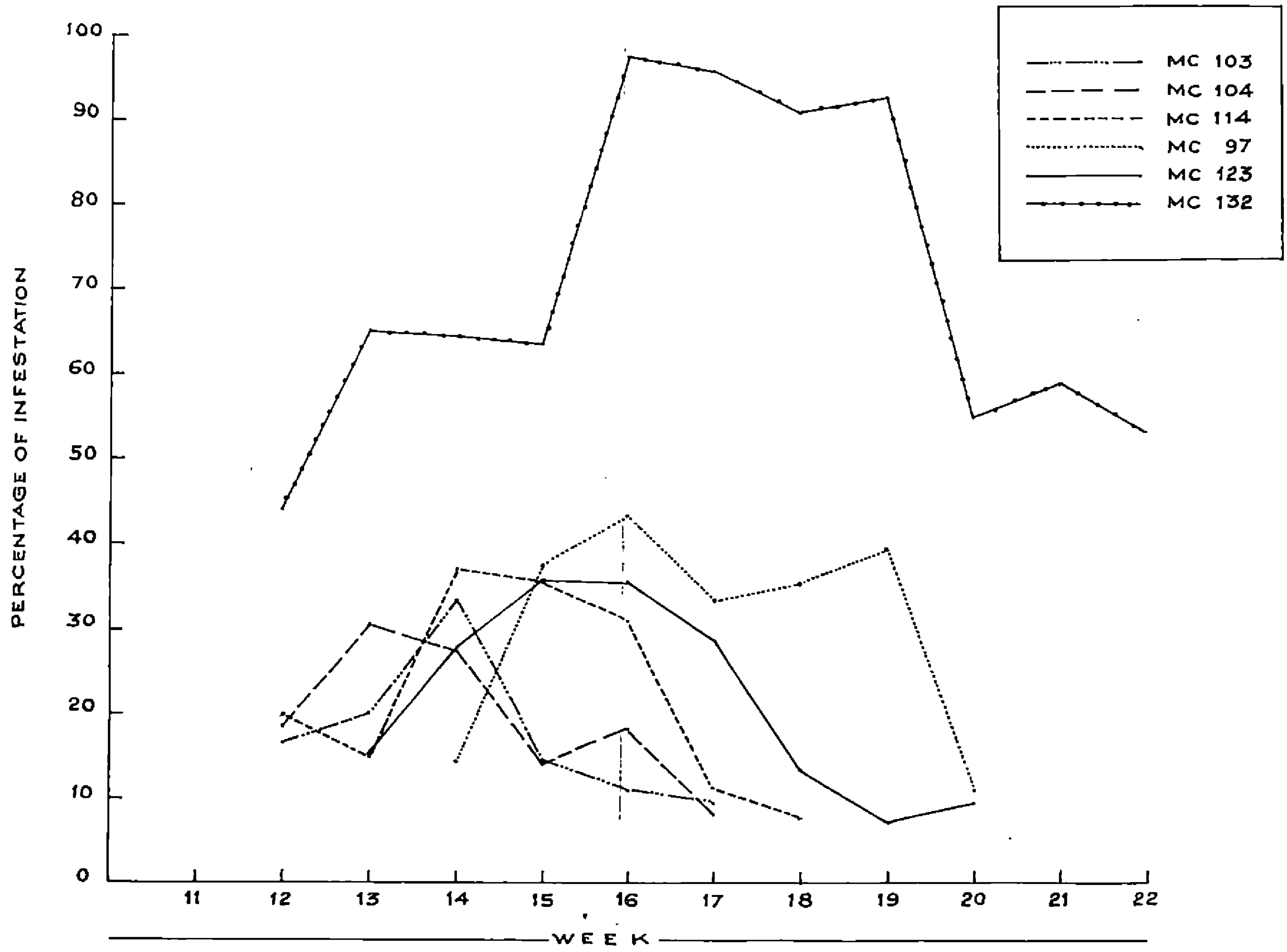
i. Orientation by fruit fly in the filter paper, impregnated with fruit juice of the accessions of bittergourd and the mean number of ovipunctures made on the filter paper

The mean number of flies which alighted on the filter paper discs impregnated with fruit extracts of the

Table 7. Mean percentage value (weekly observations) on fruit infestation in the accessions of bittergourd by D.cucurbitae from 11th week onwards after sowing in the monsoon crop

Acce-ssions	Week												
	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22nd	23rd
MC 103	-	16.75	20.00	33.35	14.50	11.25	9.85	-	-	-	-	-	-
MC 104	-	18.75	30.75	27.30	14.30	18.20	8.30	-	-	-	-	-	-
MC 114	-	20.00	14.85	37.50	35.70	30.75	11.50	7.75	-	-	-	-	-
MC 97	-	-	-	14.30	37.50	43.37	33.50	35.20	39.30	11.30	-	-	-
MC 123	-	-	15.35	28.50	35.72	35.30	28.57	13.35	7.15	9.35	-	-	-
MC 132	-	44.30	65.00	64.44	63.63	97.77	95.95	90.75	92.35	54.50	58.75	53.10	-

Fig.2 Mean percentage of fruit infestation on the accessions by *D. cucurbitae* from 11th week after sowing in the kharif crop.



MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
PERCENTAGE OF INFESTATION
0
10
20
30
40
50
60
70
80
90
100
11
12
13
14
15
16
17
18
19
20
21
22
WEEK

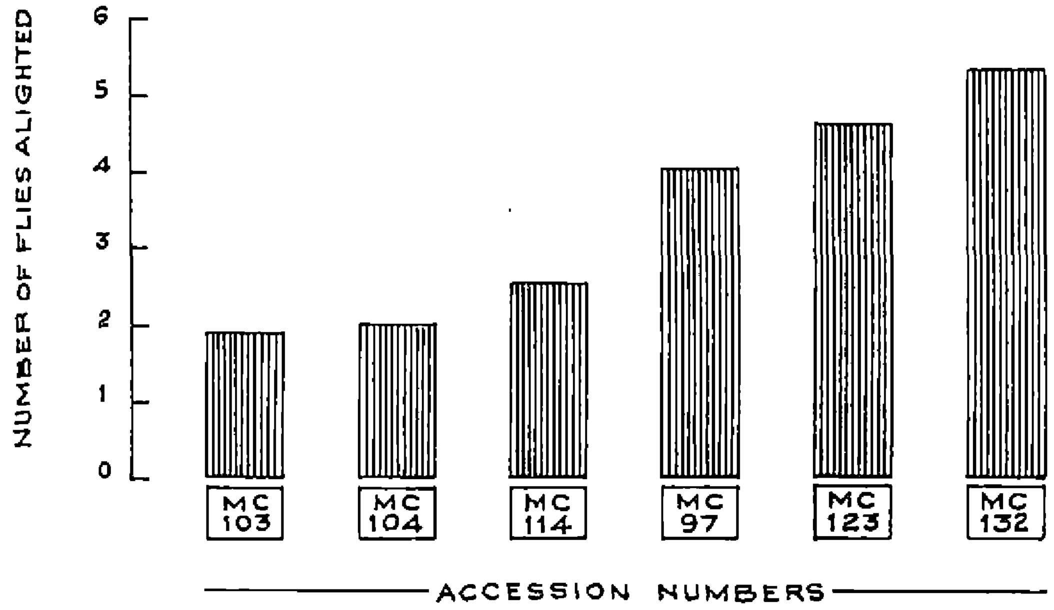
accessions are given in the Table 8 and depicted in the Fig.3. There is significant variation in the number of flies alighting on the filter papers impregnated with fruit juice of different accessions, the range being 1.833 to 5.333. The number of flies alighted on the filter paper discs impregnated with the juice of the accession MC 132 and MC 123 were comparatively higher and varied significantly from the number alighted on the filter papers impregnated with fruit juice of MC 104 and MC 103.

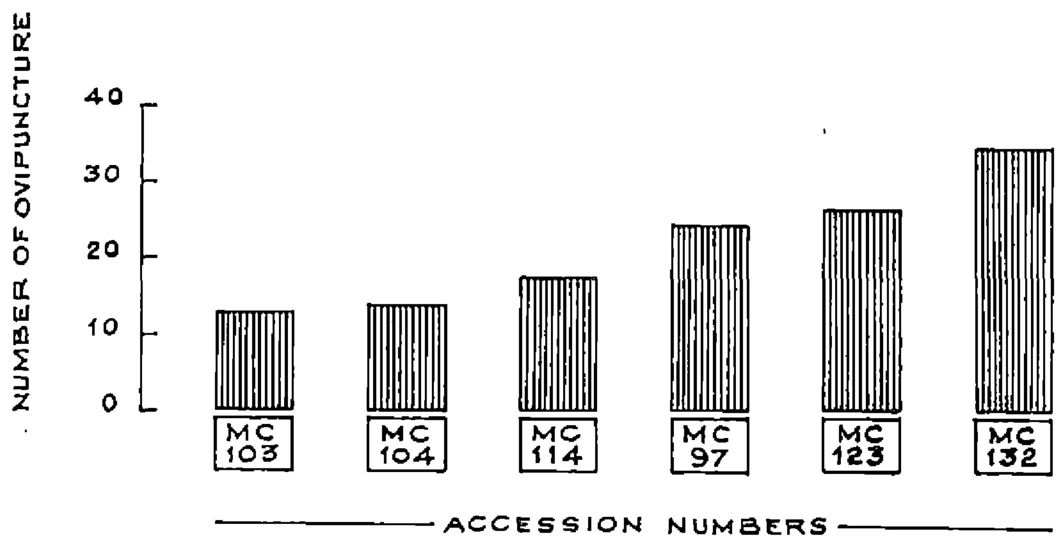
Number of ovi-punctures

The mean number of ovipunctures made by D. cucurbitae on the filter paper discs impregnated with the fruit extract of the accessions ranged from 12.5 to 34.166 (Table 8 and Fig.4). The maximum number of ovi-punctures was 34.166 in the filter paper impregnated with the fruit juice of MC 132. This was significantly at variance from those in other filter papers impregnated with the fruit extracts of other accessions. The filter papers with the fruit extracts of MC 103 and MC 104 had comparatively lower number of ovi-punctures which differed significantly from others. In the other filter papers, the number of ovi-punctures were of intermediate range.

Table 8. Orientation of adults of D. cucurbitae when exposed to filter papers impregenated with extracts of fruit of the different accessions of bittergourd

Accessions	Mean number of flies alighted in 60 minutes	Mean number of ovipunctures made in 60 minutes
MC 103	1.833	12.500
MC 104	2.000	13.833
MC 114	4.500	17.166
MC 97	4.000	25.500
MC 123	4.666	26.333
MC 132	5.333	34.166
C.D. (0.05)	1.721	4.332


NUMBER OF FLIES ALIGHTED
0
1
2
3
4
5
6
MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
ACCESSION NUMBERS


NUMBER OF OVIPUNCTURE
0
10
20
30
40
MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
ACCESSION NUMBERS

7. Ovipositional preference in the cut fruit of bittergourd

The data on the mean number of eggs laid on the fruit of different accessions of bittergourd in the no-choice test and multiple choice test are presented in Table 9 and depicted in Fig.5.

No-choice test

The mean number of eggs deposited in the cut fruit of bittergourd accessions differed significantly. As compared to 64.833 eggs deposited on the fruit of the accession MC 132, the mean number of eggs laid on the cut fruit of MC 103 was only 17.666. The mean number of eggs laid in other accessions were 20.500, 26.666, 30.166 and 43.5 in the accessions MC 104, MC 114, MC 97 and MC 123 respectively.

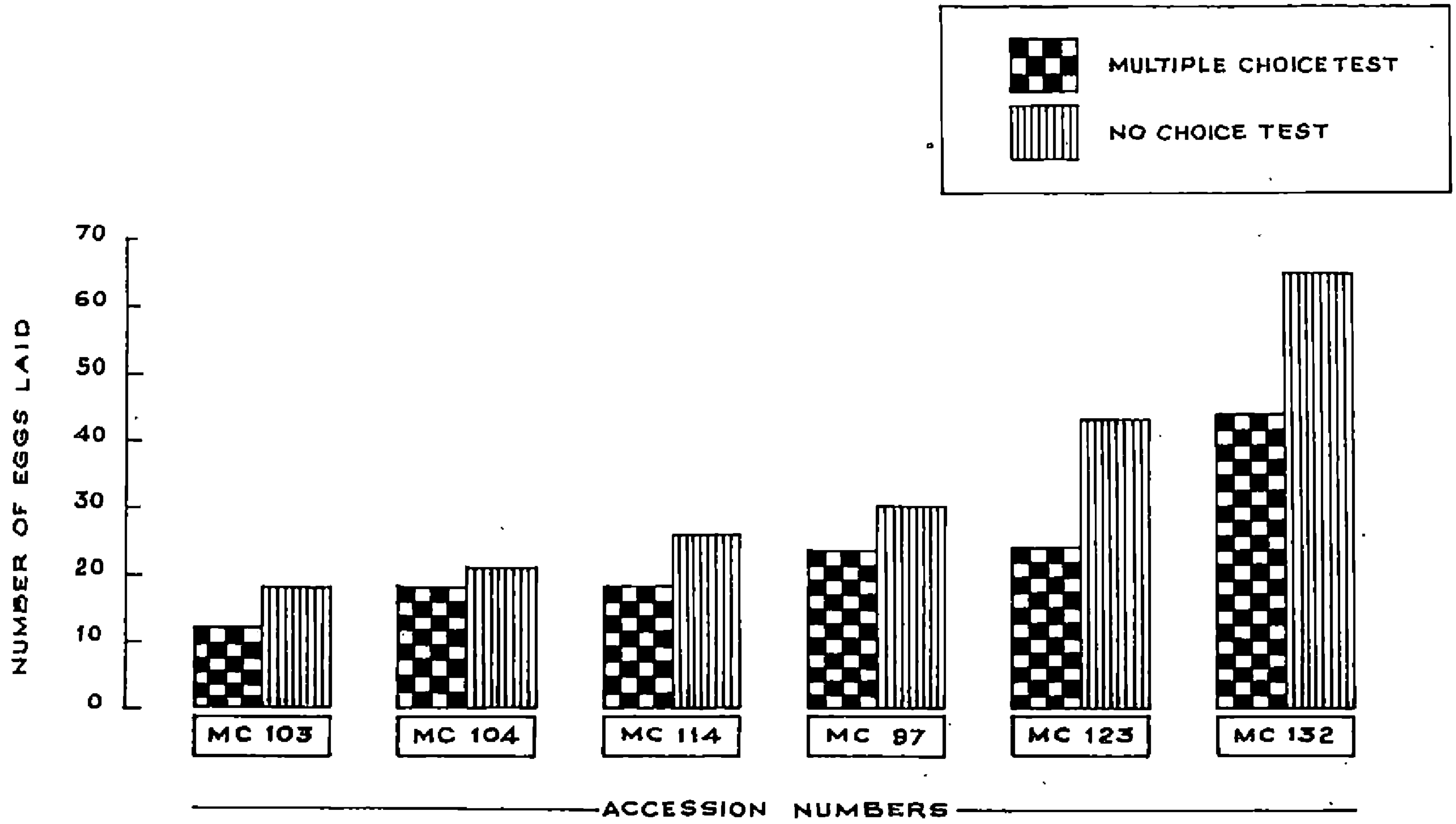
Multiple choice test

The mean number of eggs laid in the cut fruit of bittergourd by D.cucurbitae had significant variation and ranged from 12.833 to 44.333. The flies laid the maximum number of eggs (44.333) on the cut fruit of MC 132 which was significantly higher than the number of eggs in the fruit of the other accession. The number of eggs

Table 9. Ovipositional preference of D. cucurbitae when exposed to the cut fruit of the accessions of bittergourd

Accessions	No. choice test (Mean number of eggs laid)	Multiple choice test (Mean No. of eggs laid)
MC 103	17.666	12.833
MC 104	20.500	18.166
MC 114	26.666	18.666
MC 97	30.166	23.500
MC 123	43.500	24.166
MC 132	64.833	44.333
C.D. (0.05)	4.400	9.761

Fig.5. Mean number of eggs laid by *D.cucurbitae* in the no choice and multiple choice tests conducted to ascertain the ovipositional preference.


MULTIPLE CHOICE TEST
NO CHOICE TEST
NUMBER OF EGGS LAID
70
60
50
40
30
20
10
0
MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
ACCESSION NUMBERS

laid in the fruit of MC 103, MC 104 and MC 114 were 12.833, 18.166 and 18.666 respectively which were comparatively lower. The number of eggs laid on the fruit MC 97 and MC 123 were 23.5 and 24.166 respectively which were of intermediate level.

8. Larval duration and larval survival

Data on the mean larval duration and mean percentage of larval survival of D. cucurbitae reared on the fruit of the accessions of bittergourd are given in Table 10 and depicted in Fig.6 and 7.

Larval duration

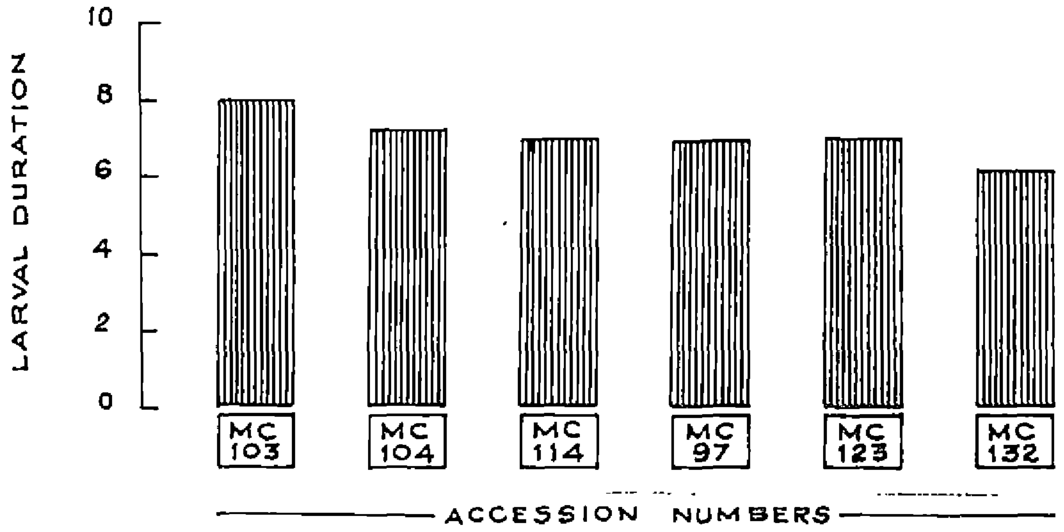
The mean length of larval duration ranged from 6.083 to 7.812 days. The shortest duration of larval stage was observed in the highly susceptible accession MC 132, which was significantly shorter than in the case of larvae reared in the other five accessions. The longest duration was observed in the larvae reared on the moderately resistant MC 103, which was significantly longer than the duration of larvae reared in all the other accessions. The larvae reared on MC 104, MC 114, MC 97 and MC 123 did not differ significantly between them.

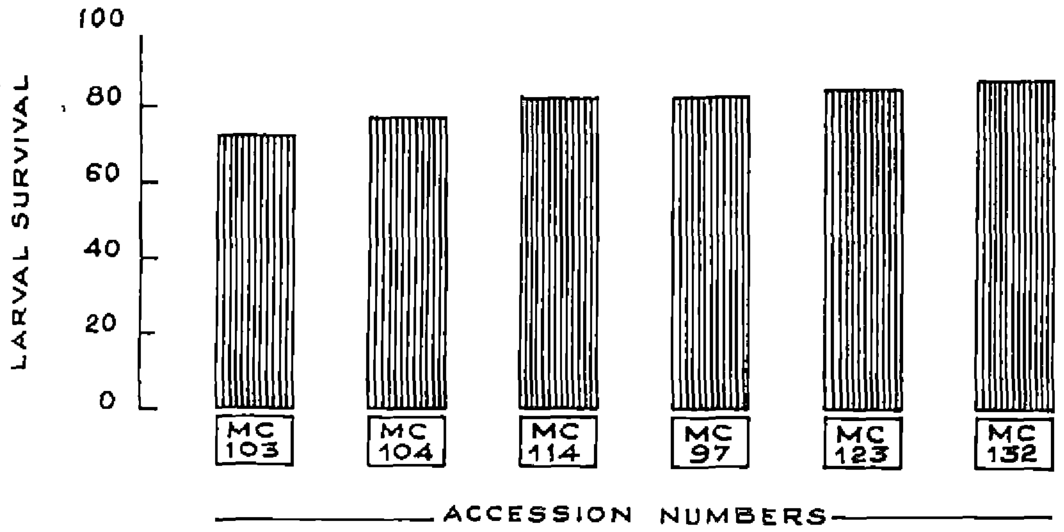
Table 10. Mean larval duration and percentage larval survival of D. cucurbitae reared on the [illegible]t of the accessions of bittergourd

Accessions	Mean duration of larval stage (days)	Mean percentage of larval survival	
MC 103	7.812	58.055	(72.00)
MC 104	7.103	62.721	(79.00)
MC 194	6.991	65.221	(82.40)
MC 97	6.900	64.932	(82.05)
MC 123	6.895	66.500	(84.10)
MC 132	6.083	68.700	(86.80)
C.D.(0.05)	0.560	3.266	

Analysis of variance for percentage of larval survival done after angular transformation.

Figures in parenthesis are the retransferred values.


10
8
6
4
2
0
LARVAL DURATION
MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
ACCESSION NUMBERS


100
80
60
40
20
0
LARVAL SURVIVAL
MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
ACCESSION NUMBERS

Larval survival

The mean percentage of larval survival ranged from 72.00 to 86.80 (Table 10). Only 72.00 per cent of larvae reared on the fruit of MC 103 survived and pupated, the value being significantly lower than all others. The larvae from the highly susceptible MC 132 had a survival rate of 86.80 per cent which was significantly higher than the survival percentage of larvae from MC 97, MC114, MC 104 and MC 103. The survival rate of larvae from other accessions were of intermediate range and did not differ significantly between themselves.

9. Pupal weight and duration

The data on the mean weight and mean duration of pupae of _D. cucurbitae_ reared on the fruit of the accessions of bittergourd are presented in Table 11.

Pupal weight

The mean weight of pupae of _D.cucurbitae_ reared on the fruit ranged from 16.667 to 17.923 mg. The highest pupal weight of 17.923 mg was recorded in the pupae reared on the fruit of the highly susceptible MC 132 and the lowest weight of 16.667 mg was recorded

Table 11. Mean pupal weight and pupal duration of *D. cucurbitae* reared on the fruit of the accessions of bittergourd

Accessions	Mean weight of pupae (mg)	Mean duration of pupal stage (days)
MC 103	16.667	8.430
MC 104	17.039	8.485
MC 114	17.153	8.117
MC 97	17.093	8.173
MC 123	17.623	7.765
MC 132	17.923	7.291
C.D. (0.05)	0.362	0.461

in the pupae from MC 103. The pupae from MC 103 had significantly lower weight than others. The pupae from MC 104, MC 114 and MC 97, among them, did not differ in their weight significantly.

Pupal period

The mean pupal duration of D. cucurbitae reared on the fruit of the bittergourd accessions ranged from 7.291 to 8.430 days. Significantly shorter pupal duration was observed in the pupae reared on the fruit of the highly susceptible accession MC 132. The highest duration of pupae was recorded in the pupae reared on the fruit of MC 103 even though it did not differ significantly from pupae of MC 104, MC 114 and MC 97.

10. Ratio of female adult emergents to males of D. cucurbitae

The mean proportion of females and the female/male ratio of adults of D. cucurbitae emerging from the fruit of the accessions of bittergourd are presented in Table 12. The adults that emerged from the fruit of MC 103 and MC 97 had less than 50 per cent females. In all other cases, the female were above 50 per cent. A high female/male sex-ratio was registered (1.584) in the highly

Table 12. Proportion of females of D. cucurbitae when reared on the fruit of bittergourd

Accessions	Mean proportion of females	
MC 103	0.412	(0.701)
MC 104	0.502	(1.008)
MC 114	0.500	(1.000)
MC 97	0.488	(0.953)
MC 123	0.557	(1.257)
MC 132	0.613	(1.584)
C.D.(0.05)	0.106	

Female/male ratio given in parenthesis

susceptible accession MC 132. The percentage of females of D. cucurbitae was less than males when reared on the fruits of MC 103 and MC 97.

11. Fecundity of females of D. cucurbitae and adult longevity

The data on the mean number of eggs laid by D. cucurbitae and the mean number of days that the adult females lived when reared on the fruit of the accessions of bittergourd are given in Table 13 and depicted in Fig. 8 and 9.

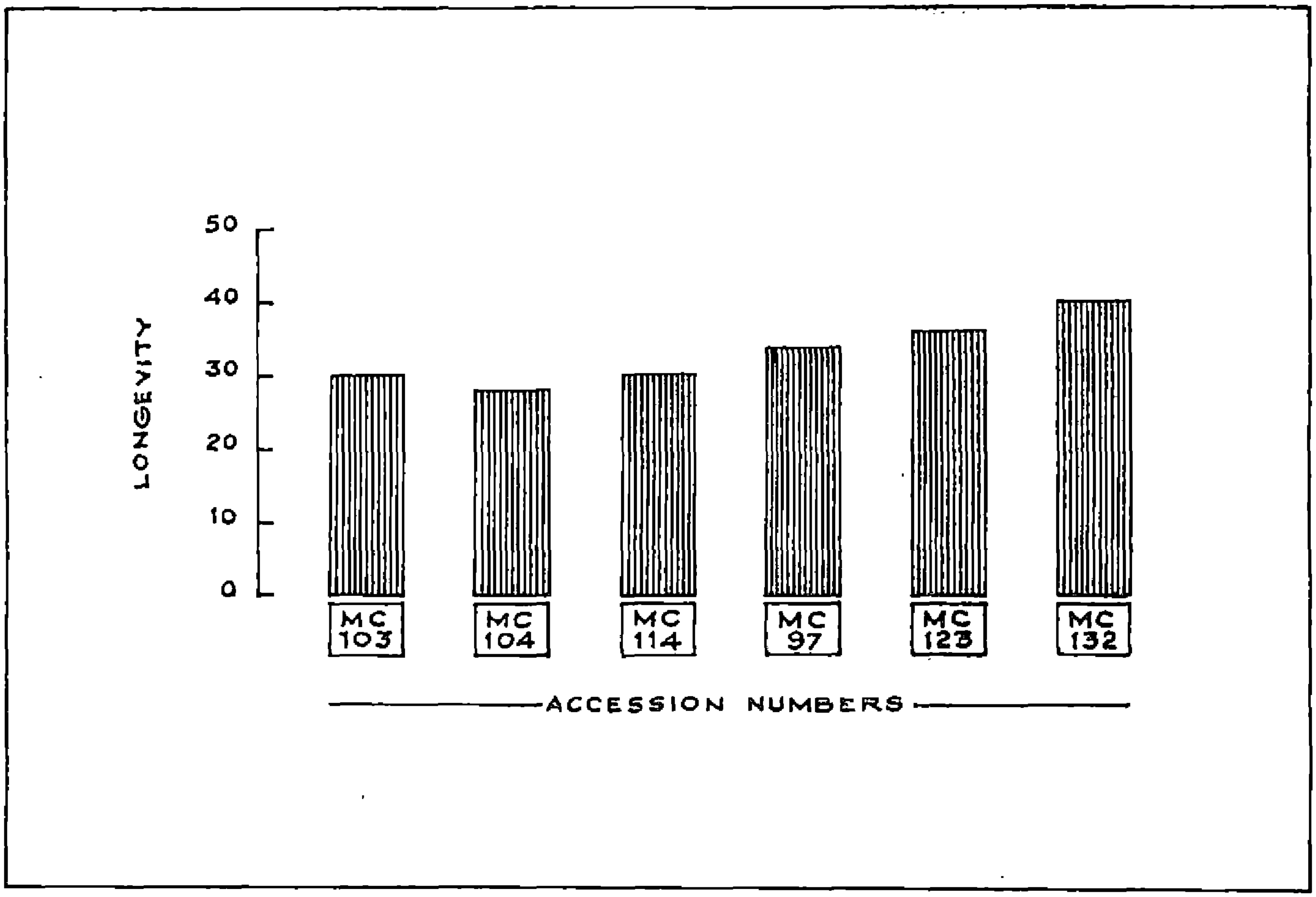
The mean number of eggs laid by the females of D. cucurbitae ranged from 111.833 to 149.166. It was observed that the lowest number of eggs (111.833) was laid by the flies when reared on the fruit of MC 103, this being significantly lower than the fecundity of females from other accessions. The numbers of eggs laid by flies reared from the fruit of MC 104 and MC 114 were 130.166 and 132.833 respectively. The highest number of eggs laid was 149.166 by the flies on the highly susceptible MC 132 which is significantly higher than the rest of the types except MC 123.

Table 13. Mean number of eggs laid and mean adult longevity of *D. cucurbitae* when reared on the fruit of the accessions of bittergourd

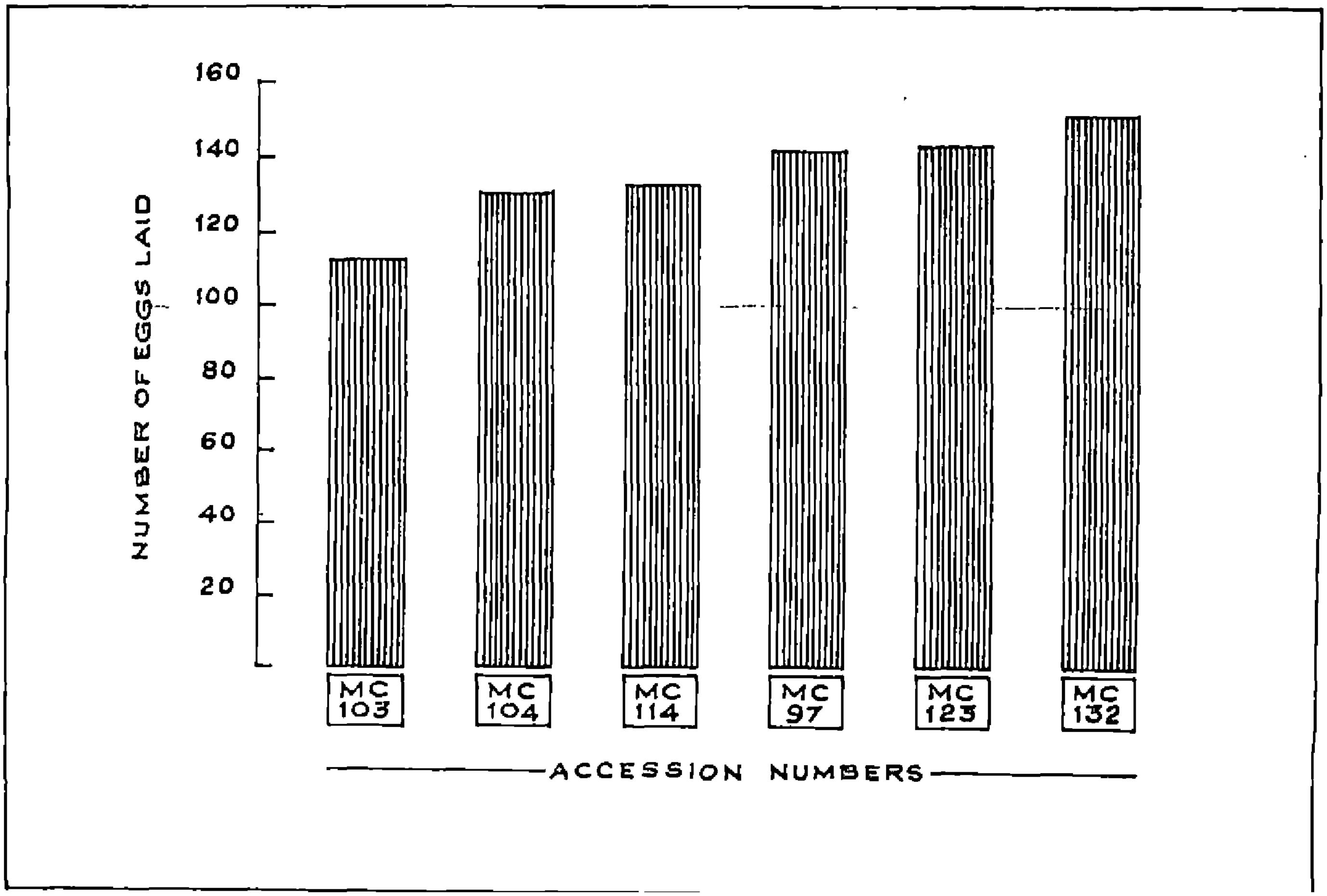
Accessions	Mean number of eggs laid	Mean longivity of adult flies in days
MC 103	111.833	29.833
MC 104	130.166	28.333
MC 114	132.833	30.333
MC 97	140.500	33.833
MC 123	143.000	35.500
MC 132	149.166	39.500
C.D.(0.05)	7.465	3.391

Fig.8 Mean longevity of adult flies when reared on the fruit of accessions of bittergourd.

Fig.9 Mean number of eggs laid when reared on the fruit of accessions of bittergourd.



LONGEVITY
50
40
30
20
10
0
MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
ACCESSION NUMBERS



NUMBER OF EGGS LAID
160
140
120
100
80
60
40
20
MC 103
MC 104
MC 114
MC 97
MC 123
MC 132
ACCESSION NUMBERS

The adult longevity of *D. cucurbitae* reared from the fruit of different accessions ranged from 29.833 to 39.500 days (Table 13). The adult longevity was significantly shorter in flies which were reared on the fruit of accession, MC 103 as compared to those reared in MC 97 and MC 123 and MC 132. The flies reared from the highly susceptible type MC 132 had the longest life span of 39.5 da, The flies from MC 97 and MC 123 showed intermedi lengths of longevity.

12. Influence of chemical ɓrs in the fruit on the infestation by *D. cucu*ɛe

The mean percentag otal sugars and crude protein in the fruit of ɕıt accessions are presented in Table 14. Tl percentage of total sugars ranged from 1.802 in the fruit of various accessions. The fruit of ision MC 132 contained the highest lev l sugars (4.271 per cent) whereas, the fr accession MC 103 contained the lowest leve cent). The mean per cent of total sugars of MC 104, MC 114, MC 97 and MC 123 are 1.8(? and 2.094 per cent respectively.

The adult longevity of *D. cucurbitae* reared from the fruit of different accessions ranged from 29.833 to 39.500 days (Table 13). The adult longevity was significantly shorter in flies which were reared on the fruit of accesssion, MC 103 as compared to those reared in MC 97 and MC 123 and MC 132. The flies reared from the highly susceptible type MC 132 had the longest life span of 39.5 days. The flies from MC 97 and MC 123 showed intermediate lengths of longevity.

12. Influence of chemical factors in the fruit on the infestation by *D. cucurbitae*

The mean percentage of total sugars and crude protein in the fruit of different accessions are presented in Table 14. The mean percentage of total sugars ranged from 1.802 to 4.271 in the fruit of various accessions. The fruit of the accession MC 132 contained the highest level of total sugars (4.271 per cent) whereas, the fruit of the accession MC 103 contained the lowest level (1.802 per cent). The mean per cent of total sugars in the fruit of MC 104, MC 114, MC 97 and MC 123 are 1.867, 1.945,2.087 and 2.094 per cent respectively.

Table 14. Mean percentage of total sugars, crude protein and sugar/protein ratio in the fruit of the accessions of bittergourd

Accessions	Total sugars (Mean %)	Crude protein (Mean %)	Sugar/protein ratio
MC 103	1.802	1.675	1.076
MC 104	1.867	1.731	1.079
MC 114	1.945	1.800	1.081
MC 97	2.087	1.832	1.139
MC 123	2.094	1.892	1.107
MC 132	4.271	3.153	1.355

The mean percentage of crude protein in the fruit of the different accessions ranged from 1.675 to 3.153. The fruit of the accession MC 132 contained the highest level of crude protein (3.153 per cent) whereas the lowest level was found in the fruit of the accession MC 103 (1.675 per cent). The percentage of crude protein in the fruit of other accessions were of intermediate in range.

The sugar/protein ratio ranged from 1.076 in MC 103 to 1.355 in MC 132. Comparatively lower sugar protein ratio was observed in the fruit of the accession MC 103, MC 104 and MC 114 the values being 1.076, 1.079 and 1.081 respectively.

Correlation coefficient between the mean percentage of total sugars and crude protein and sugar/protein ratio in the fruit and the percentage of infestation by the fruit fly D. cucurbitae

The correlation coefficients between the mean percentage of total sugars, crude protein and sugar/protein ratio of the different accessions of bittergourd on the one hand and the mean percentage of fruit infestation by D. cucurbitae on the other are presented in Table 17. Significant positive correlation was observed between the percentage of fruit infestation and crude protein content in the fruit. The correlation between the crude protein content and the mean percentage of infestation is found to be significant.

Total ash, silica and ash/silica ratio

The mean percentages of total ash and silica and ash/silica ratio found in the fruit of different accessions are presented in Table 15. The mean percentage of total ash in the fruit of bittergourd ranged from 2.358 to 6.884. The fruit of the accession MC 132 contained the maximum percentage of ash being 6.884 per cent as compared to 2.358 per cent of ash in the fruit of the accession MC 103.

The mean percentage of silica detected in the various accessions of bittergourd fruit ranged from 0.093 to 0.236 per cent. The lowest percentage of 0.093 was detected in the fruit of the accession MC 132 and the highest percentage of silica was detected in the fruit of the accession MC 103 (0.236 per cent) and MC 104 (0.234 per cent). The percentage of silica in other accessions were of intermediate levels.

Table 15. Mean percentage of total ash, silica and ratio of total ash/silica of the fruits of bittergourd accessions

Accessions	Total ash (Mean %)	Silica (Mean %)	Ash/silica ratio
MC 103	2.358	0.236	9.992
MC 104	2.819	0.234	12.047
MC 114	2.262	0.121	18.694
MC 97	3.304	0.112	29.500
MC 123	3.525	0.107	32.944
MC 132	6.884	0.093	74.022

The highest values ash/silica ratio was found in the fruit of bittergourd accession MC 132 (74.022) and the lowest values in MC 103 (9.992). The other accessions which shared higher ratio of ash/silica were MC 123 and MC 97. The accession MC 114 (18.694), MC 104 (12.047) shared lower ash/silica ratio.

Correlation coefficient between the mean percentage of total ash, silica, and ash/silica ratio and the percentage of fruit infestation by *D. cucurbitae*

Correlation coefficient between the mean percentage of total ash, silica and ash/silica ratio on the one hand and the fruit infestation by *D. cucurbitae* on the other are presented in Table 17. Significant positive correlation is found between ash/silica ratio and the mean percentage of infestation by *D. cucurbitae.*

14. Moisture content

The mean percentage of moisture detected in the fruit of different accessions of bittergourd are presented in Table 16. The moisture content of fruit ranged from 90.75 to 94.44 per cent. The minimum content of moisture was detected in the fruit of the accession MC 103. The moisture percentage of 94.44 was detected in the fruit of the accession.MC 132. The moisture percentage of the other accessions are of the intermediate level.

Correlation coefficient between the mean percentage of moisture and the percentage of fruit infestation by D. cucurbitae

The correlation coefficient between percentage of moisture in the accessions of bittergourd fruits on the one hand and the percentage of infestation by D. cucurbitae on the other are presented in Table 17. Percentage of moisture is positively correlated to the mean percentage of infestation by D. cucurbitae.

15. Total phenolics

The mean percentage of total phenolics detected in the fruit of different accessions were presented in Table 16. It has been found that the fruit of the bittergourd accession MC 132 contained the least percentage of total phenolics being 0.088 per cent. The fruit of the bittergourd accession MC 103 contained the maximum per cent of total phenolics (0.217 per cent) whereas the fruit of other accessions contained intermediate levels of total phenolics.

Table 16. Mean percentage of total phenolics and moisture contents in the accessions of bittergourd fruit

Accessions	Mean percentage of total phenolics	Mean percentage of moisture
MC 103	0.217	90.75
MC 104	0.199	91.96
MC 114	0.176	92.85
MC 97	0.136	92.55
MC 123	0.118	92.61
MC 132	0.088	94.44

Table 17. Correlation coefficient (r) between total sugars, crude protein, total sugars/protein ratio, total ash, silica, ash/silica ratio, total phenolics and moisture per cent in the fruits and the infestation of fruits by _D. cucurbitae_

	Mean percentage of fruit infestation
Mean percentage of total sugars	+ 0.078
Mean percentage of crude protein	+ 0.961*
Mean percentage of total sugars/protein ratio	+ 0.362
Mean percentage of total ash	+ 0.368
Mean percentage of silica	+ 0.428
Mean percentage of ash/silica ratio	+ 0.977*
Mean percentage of total phenolics	- 0.989*
Mean percentage of moisture	+ 0.817

* Significant at 5% level

Discussion

DISCUSSION

Sixty six accessions of bittergourd, *Momordica charantia* L., collected from various sources were screened in the field for resistance to infestation by the fruit fly, *D. cucurbitae*, during the summer season of 1984-85 in the Horticultural College farm, Vellanikkara and their levels of susceptibility to the pest were assessed based on the percentage of fruit infested. Based on the results obtained from this screening trial, twenty accessions having fruit damage of less than twenty five per cent and MC 132 as the susceptible check were further screened in the field in the kharif season of 1985-86. The plant mediated influences on growth, survival and reproduction of the insect when reared on the fruits of selected accessions were ascertained in an attempt to work out the mechanisms of resistance. The mean percentage of fruit infestation in the test accessions in the summer trial ranged from 10.866 to 74.266 (Table 2). The wide range in the levels of infestation shows wide variability in the different accessions collected for screening with respect to their relative susceptibility to the infestation by the pest.

On the basis of the results obtained from the summer season trial, the accessions were classified into four groups, namely, highly susceptible, moderately susceptible, moderately resistant and resistant. The accessions showing fruit infestations above 30 per cent were included in the highly susceptible group, while those between 20 - 30 per cent was included in the moderately susceptible group. Those accessions having fruit infestation between 10 and 20 per cent were categorised as moderately resistant. According to the criteria fixed, the accessions with less than 10 per cent fruit infestation were to be included under the resistant group. But in the summer season trial there were no accessions with less than 10 per cent fruit infestation.

Economic threshhold levels for the fruit fly in bittergourd have not been reported. Hence the criteria for the resistant group has arbitrarily been fixed based on experiences and general observations, assuming that bittergourd crop with less than 10 per cent fruit infestation may not cause any economic damage. The fruit infestation ratings of other groups were also arrived at similarly.

Accordingly, the accessions MC 103, MC 115, MC 116, MC 104, MC 88, MC 112, MC 114 and MC 122 were classified as moderately resistant, MC 96, MC 95, MC 87, MC 97, MC 98, MC 89, MC 86, MC 113, MC 123, MC 64, MC 107, MC 90, MC 39, MC 4, MC 106, MC 91, MC 105 and MC 85 were classified as moderately susceptible and MC 121, MC 124, MC 92, MC 133, MC 134, MC 84, MC 120, MC 137, MC 108, MC 111, MC 99, MC 100, MC 139, MC 138, MC 125, MC 29, MC 93, MC 119, MC 136, MC 21, MC 110, MC 102, MC 117, MC 1, MC 94, MC 109, MC 118, MC 101, MC 130, MC 3, MC 49, MC 131, MC 135, MC 129, MC 66, MC 69, MC 127, MC 126, MC 128 and MC 132 were classified as highly susceptible. None of the accessions showed less than ten per cent of fruit infestation and hence no accession could be included in the resistant group.

Twenty accessions which showed less than twenty five per cent fruit damage and the accession MC 132, which was found highly susceptible, were further screened in the field for resistance to D. cucurbitae in the following kharif season. The results revealed a more or less similar trend in respect of susceptibility/ resistance to fruit damage even though there was a slight increase in the percentage of fruit infestation during this trial.

Out of the 21 accessions tested during kharif season in the field, six were selected for detailed investigations. Three accessions belonging to the moderately resistant group, two belonging to moderately susceptible group and one belonging to the highly susceptible group were thus selected for detailed studies (Table 5).

Weekly observations taken on the infestation of bittergourd fruit by D. cucurbitae can be expected to provide information on the spread of the period of infestation in the test accessions. The weekly observations taken in the summer season crop showed that the infestation of the fruit by D. cucurbitae was restricted to a relatively shorter period in the accessions belonging to the moderately resistant group (Table 6 and Fig.1). The fruit infestation was observed from the 10th week after sowing the seeds which continued up to 14th week in the case of accession MC 103. In the accession MC 104 it was from 9th to 15th week whereas in MC 114 it was from 11th to 16th week. In the moderately susceptible MC 97 and MC 123 the durations of infestation were from 12th to 16th week and 11th to 19th week respectively.

In the highly susceptible MC 132 the infestation started in the 11th week and continued up to the 22nd week.

In the kharif season also almost similar durations of infestations were observed (Table 7, Fig.2). In both the seasons, the duration of infestation was the longest in the case of the highly susceptible MC 132, while it was comparatively shorter in the case of the moderately resistant accessions.

It is thus found that the highly susceptible accession MC 132 was prone to infestation by D.cucurbitae for a relatively longer period as compared to the moderately resistant accessions. This is explicable mainly on the basis of the plant characteristics remaining favourable for a relatively longer period in the highly susceptible accession. Similar findings were reported by Panda et al. (1971) and Nair (1983) with regard to L. orbonalis on brinjal varieties.

Painter classified the mechanisms of resistance into antibiosis, non-preference and tolerance (Painter, 1951). The mechanism of tolerance has no significance with regard to fruit infestation by D. cucurbitae in bittergourd, since the plants cannot support the insects without reduction in yield and quality of fruit.

The non-preference and antibiosis factors of resistance were investigated with respect to orientation, ovipositional preference, larval duration and survival, pupal weight and duration, female/male ratio, fecundity and longevity of adult flies of D. cucurbitae when reared on the fruit of the test accessions.

To study the nature of chemoreceptive response, filter paper discs impregnated with the fruit extracts of different accessions were exposed to the gravid females. Maximum number of flies of D. cucurbitae were observed on paper discs impregnated with the extracts of the highly susceptible accession MC 132 (Table 13). Maximum number of ovipunctures were also observed in the paper discs impregnated with the fruit extracts of the same accession. The number of gravid flies alighted and the number of ovipunctures were much lower in the paper discs impregnated with the fruit extracts of the moderately resistant accessions. These clearly show that the gravid females showed a distinct preference for oviposition on the highly susceptible accession MC 132. Similar findings were recorded by Chelliah and Sambandam (1974 a) and Gunathilakaraj and Chelliah (1985).

The ovipositional preference of the gravid females were ascertained by multiple choice test and no-choice test. Oviposition involves a series of behavioural activities which are influenced by many plant traits. Resistance to oviposition may be due to failure to produce necessary oviposition inducing stimuli or by providing oviposition inhibiting stimuli. Significant variations were noticed in the total number of eggs laid in the cut fruit of bittergourd accessions in the multi-choice and no-choice tests (Table 9). The mean number of eggs laid in the highly susceptible accession MC 132 in the no-choice test and multi-choice test were 64.833 and 44.333 respectively, which were found to be significantly higher than those found in the cut fruit of other accessions. The moderately resistant accessions MC 103 and MC 104 recorded comparatively lower number of eggs. Intermediate values were recorded in other accessions. It is evident that the female adults of D. cucurbitae showed a clear preference for the highly susceptible type, MC 132, for egg laying over the moderately resistant MC 103 and MC 104. The results of the multiple and no-choice tests also corroborated the findings from the orientational response trials.

The antibiosis factor of resistance were investigated with respect to larval duration and survival, pupal weight and duration, female/male ratio of the adult emergents, fecundity and adult longevity of D. cucurbitae when reared on the fruit of the test accessions.

The longest larval duration of 7.812 days was observed in the larvae from the fruit of MC 103, while shortest duration of 6.083 days was recorded in the larvae from the highly susceptible MC 132. These two values varied significantly from others. The larvae from other accessions showed intermediate durations.

The mean percentage of surviving and pupating larvae of D. cucurbitae varied from 72.00 in the resistant accession MC 103 to 86.80 in the highly susceptible accession MC 132 (Table 10). The larval survival from other accessions showed intermediate values.

The results of the present study agree with the reports of Bindra and Mahal (1981) and of Dutta and Saharia (1984). According to Bindra and Mahal (1981) when the cotton jassid A. biguttula biguttula was reared in a resistant bhindi plant, it resulted in prolonged nyphal stage and reduced nyphal survival of the insect. Dutta and Saharia (1984) also reported lower nyphal survival in the case of Lipaphis erysimi in resistant mustard accessions. Similar results were obtained by Durbey and Sarup (1984) in the case of Chilo partellus in resistant rice varieties and Nair (1983) in the case of L. orbonalis in resistant brinjal accessions.

As in the case of larval duration, pupal duration also revealed similar trend. The duration was longer in the case of pupae reared on the fruit of moderately resistant accessions compared to those reared on the fruit belonging to the highly susceptible accession.

The pupal weight of D. cucurbitae was the highest when reared on the fruit of the highly susceptible accession MC 132, the value being 17.923 mg, while the lowest weight of 16.667 mg was observed in the pupae developed on the moderately resistant accession MC 103 which was significantly lower than all other values (Table 11). The pupae from the moderately resistant accessions MC 104 and MC 114 and the moderately susceptible MC 97 recorded significantly lower weights than the pupae from the highly susceptible MC 132. The shortest duration of 7.291 days was recorded in the pupae from the highly susceptible MC 132 which was significantly shorter than others (Table 11). The duration of pupal stage when reared from the fruit of moderately resistant MC 103, MC 104, and MC 114 and the moderately susceptible MC 97 did not vary among themselves.

The results obtained are in full agreement with the reports of Chelliah and Sambandam (1974 b) that higher pupal weight and longer pupal durations were observed in D. cucurbitae reared in the resistant Cucumis callosus. Nair (1983) also reported that there was a prolongation of pupal period and reduction in weight of pupae when L. orbanalis was reared in the resistant brinjal accessions.

The female/male ratio of adults of D. cucurbitae when reared on the fruit of different bittergourd accessions varied significantly. The ratios were more than one in the case of the accessions, MC 132, MC 123, MC 114 and MC 104 indicating preponderance of females. In the case of the accessions MC 103 and MC 97 the ratio is less than one indicating that the population of females were less than the males (Table 12).

These results are in conformity to the report of Durbey and Sarup (1984) that lower female/male ratio of *Chilo partellus* (Swinhoe) were obtained in the resistant maize varieties. Similar results were reported by Chelliah and Sambandam (1974 b) in the case *D. cucurbitae* reared on resistant *C. calloeus*, by Nair (1983) in the case of *L. orbonalis* reared on resistant brinjal accessions and by Lall and Sukhami (1982) in the case of *C. partellus* reared on resistant Sorghum varieties.

The higher values of female/male ratio in the case of insects reared from highly susceptible accessions as compared to those from moderately resistant accessions showed that there was a dominance of females when reared in the highly susceptible accession. This can be normally expected in the case of susceptible accessions since faster increase in the pest population can be ensured only when there is a dominance of females.

The total number of eggs laid by adult females *D. cucurbitae* reared from the different bittergourd accessions varied significantly (Table 13). Maximum number of eggs were laid by the fly reared on the fruit of highly suceptible accession MC 132 (149.166). Significantly lower number of eggs was laid by the fly reared on the fruit of MC 103 than MC 132. The number of eggs laid by the flies reared on the fruit of other accessions were of intermediate values.

The findings that lower number of eggs were laid by the flies reared from the moderately resistant accessions agree with the report of Chelliah and Sambandam (1974 b). They reported that lower number of eggs were laid by D. cucurbitae when reared on the resistant C. callosus. Same results were obtained by Dutta and Saharia (1984) in the case of Lipaphis erysimi in resistant mustard varieties.

The adult longevity of D. cucurbitae when reared on different accessions of bittergourd showed significant variation. While the adult flies reared on the highly susceptible MC 132 lived up to 39.5 days, it was 29.833 days in the case of adult flies reared on the moderately resistant accession MC 103 (Table 13).

The shortening in the adult life span of insects reared on the resistant accessions was reported by

Chelliah and Sambandam (1974 b) in the case of *D. cucurbitae* reared from the resistant *C. callosus* and by Gunathilakaraj and Chelliah (1985) in the case of *Sogatella furcifera* in resistant rice varieties.

Prolonged larval and pupal periods, reduced pupal weight, lower number of eggs laid by adult females, unfavourable female/male ratio, fewer larvae completing development and lower adult longevity are some of the adverse effects in herbivores due to antibiosis in resistant accessions. This has been reported by several workers (Durbey and Sarup, 1984; Beach *et al.*, 1985; Chelliah and Sambandam, 1974 b; Isahaque and Chaudhuri, 1984 b; Nair, 1983; Dutta and Saharia, 1984; Gunathilakaraj and Chelliah, 1985; Ofuyu and Akingbohungbe, 1986). In the present study also it was found that antibiosis in the moderately resistant accessions resulted in reduced pupal weight, longer larval and pupal period, reduced survival of larvae, lower female/male ratio, shorter adult longevity and lower fecundity in the fruit fly, *D. cucurbitae*.

Deficiency, imbalance or absence of essential nutrients or the presence of toxic chemicals in the host plant have been attributed either individually or jointly as bases of antibiosis (Dhillion, 1986; Boughdad et al., 1986; Chelliah and Sambandam, 1973 and Panda and Das, 1975). In the present study also the imbalance or lack of essential nutritional materials or presence of toxic chemicals might have operated as possible bases of antibiosis.

Plant chemicals influence the physiology of insect pests which feed on them in various ways. The growth and development are very much affected by the chemical constituents of the host plants. Renwick (1983) reported that the selection and avoidance of potential hosts by phytophagous insects are guided by a combination of complex physical and chemical stimuli. Hsiao (1972) and Thorsteinson (1960) stated that the chemical composition of plants is of fundamental significance in the acceptance or rejection of host plants either for food or for oviposition. Biochemical factors of the plant is more important in regulating resistance than the bio-physical factors against crop pests (Sambandam and Chelliah, 1973). In the present investigations the biochemical constitution of fruit in terms of total sugars, crude protein, total ash, silica and total phenolics were studied.

The highest quantities of total sugars and crude proteins were recorded in the fruit of the highly susceptible MC 132, whereas the values were comparatively lower in the moderately resistant MC 103, MC 104 and MC 114. Intermediate values were recorded in the moderately susceptible MC 97 and MC 123 (Table 14). That the higher levels of total sugars and crude protein are related to higher levels of susceptibility to pests have been reported by many workers (Isahaque and Chaudhuri, 1984; Srivastava et al., 1978; Beck, 1974; Knap et al., 1966). Srivastava et al. (1978) reported that fructose, sucrose, ribose and maltose are essential for the proper growth of D. cucurbitae. According to Pal et al. (1983), the accessions of musk melon resistant to fruit fly D. cucurbitae contained low total soluble sugars.

On the other hand, there are many reports on the association of resistance to pests in crop varieties with higher content of sugars (Bell, 1982; Chaabra et al., 1984; Gill and Bakhetia, 1985; Krishnananda, 1973; Jayaraj, 1967). The variation in the influence of sugars on the extent of susceptibility to crop pests is expected in the light of the variations in the nutritional requirements of the insect species and the precise role of sugars as phagostimulants to different species. In bittergourd it is indicated that the susceptibility to fruit infestation by *D. cucurbitae* is related to higher levels of total sugars.

Nair (1983) reported that lower quantity of crude protein and total sugars were found in brinjal varieties resistant to the attack of *L. orbonalis*. Singh (1988) found low levels of total sugars, reducing sugars and protein in the leaves of Okra resistant to *A. biguttula biguttula*. Similar results were obtained by Chelliah (1972) in *C. callosus* resistant to *D. cucurbitae*. The results of the present studies are also in agreement with their findings.

The sugar/protein ratio in the fruit was also found to be lowest in MC 103 and highest in MC 132. The ratios of other accessions did not show significant variations.

Correlation coefficients worked out between the mean percentage of total sugars, crude protein, sugar/ protein ratio in the fruit on the one hand and the percentage of infestation by fruit fly in the other, showed that the correlation between the crude protein content and the fruit infestation by fruit fly was positive and significant. No significant correlations were observed between the total sugars and mean percentage of infestations.

The mean percentage of total ash content was the highest in the fruit of the highly susceptible MC 132. The moderately susceptible and moderately resistant accessions recorded comparatively lower contents of total ash.

The percentage of silica also varied in the fruit of different accessions of bittergourd. The percentage of silica content was the lowest in the highly susceptible accession MC 132 and highest in the accession MC 103 and MC 104. There was no significant correlation detected between the percentages of ash & silica on the one hand and the percentage of infestation on the other.

Higher values of ash/silica ratio were obtained in the highly susceptible accession, as compared to moderately resistant ones. The correlation coefficient involving these ratios on the one hand and the percentage of fruit infestation on the other was positive and significant.

The role of total ash and silica in imparting resistance in plants against insects has been reported by some workers (Kleber, 1983; Nair, 1983, Panda *et al*., 1975). According to them, the higher the content of silica, the lesser will be the attack by insect pests. Panda and Das (1975) detected higher quantity of silica in the varieties of brinjal resistant to *L. orbanalis*. Nair (1983) also obtained similar result in brinjal against *L. orbonalis*. The results of the current studies also are in line with the above findings.

The total phenolic content ranged from 0.088 to 0.217 in the fruit of different accessions. Comparatively higher percentage of total phenolics was found in the fruit of accession MC 103, MC 104 and MC 114. The highly susceptible accession MC 132 contained the lowest percentage of total phenolics.

Significant negative correlation is found between the mean percentage of total phenolics and the percentage of fruit infestation by *D. cucurbitae*. The broad spectrum defensive mechanism provided by phenolic compounds in plants against crop pests have been reported in muskmelon (Chelliah, 1971); *Solanum* (Sambandam *et al*., 1976); Soyabean (Chiang and Norris, 1983; Chiang, 1984); Bhindi (Uthamaswami, 1980); Brasicca (Singh *et al*., 1987) and in Brinjal (Nair, 1983). The present study also is in conformity to their findings.

Mean percentage of moisture content in the accessions ranged from 90.75 to 94.44. Comparatively higher percentage was detected in the highly susceptible MC 132 and lowest percentage of 90.75 was detected in the moderately resistant accession MC 103.

Relationship of moisture content to the infestation of insect pests was earlier observed in cow pea varieties infested by aphid A. craccivora (Bell, 1982). Total moisture content in the susceptible cow pea accessions were found to be more than in resistant accessions.

In the present investigation, the accessions MC 103, MC 104 and MC 114 have been identified as moderately resistant to the infestation by D. cucurbitae with the help of field and laboratory trials. An attempt has been made to work out the mechanisms of resistance with respect to orientational response, ovipositional preferences, larval duration and survival, pupal period and weight, female/male ratio, fecundity and adult longevity of the insect. The biochemical constitutions of the fruits of the test accessions were also ascertained and correlated with the levels of fruit infestation by the insect.

Summary

SUMMARY

In studies on the host plant resistance in *MAmordica charantia* L. to infestation by the fruit fly *Dacus cucurbitae* Coq. (Tephritidae : Diptera), a field trial for screening sixty six accessions of bittergourd was laid out in the summer season of 1984-85 in the Horticulture College Farm, Vellanikkara. The mean percentage of fruit infestation in the accessions ranged from 10.866 to 74.266. Based on the levels of fruit infestation, the accessions were classified as highly susceptible (more than 30 per cent) moderately susceptible (between 20 and 30 per cent) and moderately resistant (between 10 and 20 per cent)

Twenty accessions which showed less than twenty five per cent fruit damage and the highly susceptible MC 132 as the susceptible check were further screened in the field for resistance to *D. cucurbitae* during the kharif season of 1985-86. The results in the kharif season trial revealed a more or less similar trend in respect to the levels of fruit infestation as obtained in the summer season trial.

Weekly observations on the fruit infestations in the field screening trials showed that in the accessions belonging to the highly susceptible and moderately susceptible groups, the fruit infestation commenced earlier and lasted for a longer duration as compared to the trend in the accessions belonging to the moderately resistant group.

The antixenosis factor of resistance were investigated with respect to orientational response and ovipositional preference of adult flies. Studies on the orientation of adult flies towards filter paper discs impregnated with fruit juices of the test accessions revealed that the flies had a positive attraction to the filter papers impregnated with the fruit juice of the highly susceptible accession MC 132 and the moderately susceptible MC 123 and MC 97. The number of ovipunctures were also significantly higher in the filter papers impregnated with fruit juices of the same accessions.

The ovipositional preference of the fruit fly were ascertained by exposing the adult flies to the cut fruits of the accessions in no-choice and multiple choice tests. The results of both the tests revealed that the flies showed a marked preference to the fruits of the highly susceptible accession for egg laying.

The antibiosis factor of resistance, with respect to larval duration and survival, pupal weight and duration, female/male ratio of adult emergents and fecundity and longevity of adults of D. cucurbitae, when reared on the test accessions were also investigated.

The larval and pupal durations were longer, when reared on the fruits of the moderately resistant accession MC 103, as compared to those reared in the fruits of the highly susceptible accession MC 132.

The percentage of larvae surviving and pupating varied from 72.666 in the moderately resistant MC 103 to 86.833 in the highly susceptible accession MC 132. The pupal weight were the highest when reared on the fruits of the highly susceptible accession MC 132.

The female/male ratio, fecundity and the longevity of the adult flies also varied significantly. The flies reared on the fruits of the accession MC 132 laid the maximum number of eggs and lived the maximum number of days as compared to the flies reared in the fruits of the moderately resistant accession MC 103. The female/male ratio was also higher in the flies reared from the fruits of highly susceptible accession MC 132.

The biochemical constitution of the fruits of the accessions in terms of total sugars, crude protein, total ash, silica, moisture and total phenolics were estimated and correlations with fruit infestation by *D. cucurbitae* were worked out.

Higher quantities of total sugars, crude protein, total ash and moisture were recorded in the fruits of the accession MC 132, whereas the values were comparatively lower in moderately resistant accession MC 103. Significant positive correlation was detected between the crude protein content and percentage of fruit infestation by fruit fly. The sugar/protein ratio and ash/silica ratio were found to be lower in the fruits of the moderately resistant MC 103 and higher in the fruits of MC 132.

The percentage of silica and total phenolics were found to be the lowest in the fruits of the highly susceptible accession MC 132. The highest silica content was recorded in the moderately resistant accession MC 103.

References

REFERENCES

Batra, R.C. and Sandhu, G.S. (1983). Mechanism of resistance in Troyer-citrage to citrus leaf miner. J. Res. Punjab agric. Univ. 20: 558-559.

Beach, R.M., Todd, J.W., Baker, S.H. (1985). Antibiosis of four resistant genotypes to the soyabean looper (Lepidoptera: Noctuidae), Environ. Entomol. 14: 531-534.

Beck, S.D. (1965). Resistance of plants to insects. A. Rev. Entomol. 10: 207-232.

Beck, S.D. (1974). Theoretical aspects of host plant specificity in insects. In proceedings of Summer institute on Biological control of plants, insects and diseases, Maxwell F.G. and Harris F.A. Univ. Press, Mississipi, Jackson.

Bell, C. (1980). Studies on the resistance in cow pea *Vigna unguiculata* walp. to the aphid *Aphis craccivora* M.Sc. thesis, Tamil Nadu Agric. University, pp.99.

Bindra, O.S. and Mahal, M.S. (1981). Varietal resistance in egg plant (brinjal) *Solanum melongena* L. to the cotton jassid *Amrasca biguttula biguttula* Phytoparasitica 9: 119-131.

Boughdad, A., Gillan, Y., Gagnepain, C. (1986). The effects of condensed tannins from broad beans (*Vicia faba*) husks on the larval development of *Callosobruchus maculatus*. Entomol. exp. appl. 42: 125-132.

Brett, C.H. and Sullivan, M.J. (1970). Vegetable insect control. North Carolina Exp. Sta. Bull. 440.

Cartier, J.J. (1963). Varietal resistance of pear to pea aphid bio types under field and green house conditions. J. econ. Entomol. 56: 205-213.

Chalfant, H.B. and Brett, C.H. (1967). Inter-relationship of cabbage variety, season and insecticide on control of cabbage looper and the imported cabbage worm. J. econ. Entomol. 60: 687-690.

*Chelliah, S. (1972). Some investigations on musk melons and Cucumis callosus R. on resistence to the fruit fly Dacus cucurbitae Coq. (Tephritidae : Diptera) Ph.D. thesis, Annamalai University, India.

Chelliah, S. and Sambandam, C.N. (1971). Role of certain mechanical factors in Cucumis callosus (Rottl.) in imparting resistance to Dacus cucurbitae Coq. Ibid. 3: 48-53.

Chelliah, S. and Sambandam, C.N. (1973). Distribution of amino acids in Cucumis callosus (Rottle Congn. and Cucurmis melo L. in relation to their resistance and susceptibility to Dacus cucurbitae Coq. (Diptera Tephritidae) Labdev. J. Sci. Technol. 11-8 (3-4): 41-43.

__________ (1974a). Mechanisms of resistance in Cucumis callosus (Rottle) Congn. to the fruit fly Dacus cucurbitae Coq. Tephritidae - Diptera) non-preference. Indian J. Entomol 36: 98-102.

Chelliah and Sambandam (1974b). Mechanisms of resistance in Cucurmis callosus (Rottle) Congn to the fruit fly Dacus cucurbitae Coq. 11. Antibiosis. Indian J. Entomol. 36: 290-296.

*Chelliah, S. and Sreenivasan, K. (1983). Resistance in bhindi, brinjal and tomato to major pests/ insects and mite pests. Abstract of papers, National Seminar on Breeding Crop Plants for Resistance to Pests and Diseases, Tamil Nadu Agric. University, Coimbatore.

Chhabra, K.S., Kooner, B.S., Sexena, A.K. and Sharma, A.K. (1984). Influence of bio-chemical components on incidence of insect pests and yellow mosaic virus in Blackgram. Indian J. Entomol. 46: 148-156.

*Chiang, H.S. (1984). Soyabean resistance to stem mining agromyzid bean flies (Diptera - Agroomyzidae) Diss. Abstr. Int. (Sci. Engg.) 44 (11): 3296B.

Chiang, H.S. and Norris, D.M. (1983). Phenolic and tannin contents as related to anatomical parameters of soyabean resistance to Agromyzid beanflies. J. agric. Food Chem. 31: 726-730.

*Cole, R.A. (1985). Relationship between the concentration of chlorogenic acid in carrot and the incidence of carrotfly larval damage. Ann. appl. Biol. 106: 211-217.

Dhillion, N.P.S. (1986). Growth of army worm Spodoptera - littoralis Boised on three selections of lycopersicon and on various concentrations of alphatomatine in artificial diets. Crop Research 26 (1): 79-82.

Dimock, M.B., Lapointe, S.L. and Tingey, W.M. (1986). Solanum neocardenasii a new source of potato resistance to the Colarado potato beetle (Coleoptera: Chryosomelidae) J. econ. Entomol. 79 (5): 1269-1275.

Doharey, K.L.(1983). Bionomics of fruit flies on some fruits. Indian J. Entomol. 45: 406-413.

Doharey, K.L. and Dhamo K.Butani (1986). Eco-toxicological studies on Dacus spp. Pesticides 20 (10: 14-15.

*Durbey, S.L., Sarup, P. (1984). Biological parameters related to antibiosis mechanism of resistance in Maize varieties to Chilo Partellus (Swinhoe) J. Entomol. Res. 8 (2): 140-147.

Dutta, S.K. and Saharia, D. (1984). Reaction of certain mustard varieties to Lipaphis erysimi (Kith.) (Aphididae : Homoptera) J. Res. Assam. agric. Univ. 5 (1): 72-78.

*Elsey, K.D. (1985). Resistance mechanism in Cucurbita-moschata to pickle worm and melon worm (Lepidoptera Pyralidae) J. econ. Entomol. 78: 1048-1051.

Etzel, R.W. and Meyer, J.R. (1986). Resistance in bluberries to feeding and oviposition by the sharpnosed leaf hopper Scaphytopius magdalensis Provancher. (Homoptera: Cicadelidae) J. econ. Entomol. 79 (6): 1513-1515.

Gilbert, B.L.; Baker, J.E. and Nooris, D.M. (1967). Juglone (5-hydroxy-1, 4-naphth oquinone) from carya ovata a deterrent to feeding by Scolytus maltistriatus. J. insect physiol. 13: 1453-1457.

*Gill, R.S., Bakhetia, D.R.C. (1985). Resistance of some Brasicca napus and B. compestris to the mustad aphid. J. of oil seed Res. (2): 227-239.

Gunathilakaraj, K. and Chelliah, S. (1984). Varietal resistance of rice to white backed plant hopper. International Rice Research News letter 9 (5): 8.

*Hanover, J.W. (1975). Physiology of tree resistance to insects. A. Rev. Entomol 20: 75-95.

Hebbs, E.T., Dahlman, D.L. and Rice, R.L. (1964). Potato Foliage sugar concentration in relation to infestation by the potato leaf hopper Emposca fabae (H.) (Homoptera : Cicadelidae). Ann. Entomol. Soc. Am. 57: 517-521.

*Horber, E. (1980). A classification of resistance types and in breeding plant resistant to insects. Ed. E.G. Maxwell and P.R.Jennings, John Wiley and Sons, pp.15-22.

*Hsiao, T.H. (1969). Chemical basis of host selection and plant resistance in oligophagous insects. Entomol. exp. appl. 12: 777-788.

Isahaque N.M.D. and Chaudhuri, R.P. (1984a). Larval developmental behaviour of Leucinodes orbonalis Guen. reared on some brinjal varieties. J. Res. Assam agric. Univ. 5 (1): 93-97.

________________ (1984b). Comparitive susceptibility of egg plant to shoot and fruit borer in Assam. Indian J. agric. Sci. 54 (9): 751-756.

√Jayaraj (1976). Research on resistance in plants to insects and mites in Tamil Nadu. Tamil Nadu Agric. Univ. Tech. Bull 2: 65 pp.

√Kennedy, J.S., Booth C.O. and Kershaw, W.J.S. (1961). Host finding by aphids in the field 111. Visual attraction Ann. appl. Biol. 49: 1-24.

Kennedy, G.G. and Sorenson, C.F. (1985). Role of glandular trichomes in the resistance of Lycopersicon hirsutum, L. glabratum to colarado potato beetle (Coleoptera : Chrysomelidae). J. econ. Entomol. 78 (3): 547-555.

*Khan, Z.R., Ward, J.Z. and Norris, D.M. (1986). Role of trichomes in soyabean resistance to cabbage looper Trichoplusia ni, Entomol. exp. appl. 42: 109-117.

Khaemba, B.M. (1985). Sources of resistance to the common pea pod and sucking bugs Riptortus dentipens and Anoploenemis curvipens in cow pea. Turrialba 35: 209-213.

Khurana, A.D. and Verma, A.N. (1983). Some biochemical plant characters in relation to susceptibility of surghum to stem borer and shoot fly. Indian J. Entomol. 45: 29-37.

Knap, J.L., Hedin, P.A. and Douglas, W.A. (1966). A chemical analysis of corn silk from single crosses of dent corn rated as resistant, intermediate and susceptible to corn earworm J. econ. Entomol. 59:1062-1064.

Krishnananda, N. (1973). Studies on resistance to jassid Amrasca devastans (Dist.) (Jassidae : Homoptera) in different varieties of cotton. Entomologists News letter 31 (1): 1-2.

Krishnaiah, K. and Vijai, O.P.(1975). Evaluation of brinjal varieties for resistance to fruit and shoot borer Leucinodes orbonalis Guen Indian J. Hort. 32 (1 & 2): 84-86.

Lall, B.S. and Sinha, S.N. (1959). On the Biology of the Melon fly Dacus cucurbitae (Coq) Sci. and Cul. 25: 159-161.

Lall, G. and Sukhani, T.R. (1982). Antibiotic effect of some resistant lines of sorghum on post larval development of Chilo parcellus (S.) Indian J. agric. Sci. 52: 127-129.

Lema, K.M.(1986). Further studies on green mite resistance in cassava. IITA Res. briefs 7: 1.

Leszezynski, B., Warchol, J. and Nira, S. (1985). The influence of phenolic compounds on the preference of winter wheat cultivars by cereal aphids. Insect science and its application 6 (2): 157-158.

Liu, Y.C. and Leey, K. (1987). Soil physical factors affecting pupal population of melon fly. Plant Protection Bulletin, Taiwan, 29 (3): 263-275.

Maxwell, F.G.(1972). Host plant resistance to insects nutritional and pest management relationships in Insect and Mite nutrition (ed. J.H.Rodriguez) North Holland Publishing Company, Amsterdam, pp. 599-62.

*Mehto, D.N. and Lall, B.S. (1981). Comparative susceptibility of different brinjal cultivars against brinjal fruit and shoot borer. Indian J. Entomol. 43: 108-109.

Nair, G.M. (1983). Host Resistance in Brinjal varieties to the fruit and shoot borer. Leucinodes orbonalis (Guen) (Lepidoptera: Pyralidae) unpublished Ph.D. thesis, Kerala Agricultural University, pp.182.

Nair, G.M. and Abraham, C.C. (1987). Ovipositional preference of *Leucinodes orbonalis* Guen. to some accessions of brinjal and related species. Abstract of papers presented at the National Symposium on Integrated Pest Control Progress and Perspectives, Trivandrum.

Narayanan, E.S. and Batra, H.N. (1960). Fruit flies and their control ICAR, New Delhi. pp.68.

Natarajan, K. (1971). Some studies on the egg plant and certain wild solanum species for resistance to *Epilachna viginctioctopunctata* (Coleoptera : Coccinellidae). M.Sc. Thesis Annamalai University.

Niraz, S., Leszezynski, B., Clepiela, A., Urbanska, A. and Warchol, J. (1985). Biochemical aspects of winter wheat resistance to aphids. Insects Sci. and appli. 6: 253-257.

*Ofuya, T.I. and Akingbohungbe, A.E. (1986). Aspects of varietal resistance in cow pea to black cow pea moth *Cydia ptychora* (Meyrick) Insect sci. and appli. 7: 777-780.

Ortu, S. (1982). Observation on the temperory resistance of fruits of some species to the attack of *Ceratitis capitata* Wied. in Surdinia. Studi Sassaresi 29: 159-172.

Painter, R.H. (1951). Insect resistance in crop plants. Mac Millan New York. pp.520.

Painter, R.H. (1958). Resistance of plants to insects: A. Rev. Entomol. 3: 267-290.

Panda, N. (1976). Role of chelated boron and zinc in host plant resistance of rice to yellow borer Tryporyza incertulas Walker. Proc. 63rd Ind. Congr. 111, 48.

*Panda, N. (1979). Principles of host plant resistance to insect pests. Hindustan Publishing Corporation, Delhi. pp.386.

Panda, N. and Das, P.C. (1974). Ovipositional preference of shoot and fruit borer Leucinodes orbonalis Guen. to some varieties of brinjal. South Indian Hort. 22: 46-50.

*Panda, N. and Das, R.C. (1975). Antibiosis factor of resistance in brinjal varieties to shoot and fruit borer Leucinodes orbonalis Guen. South Indian Hort. 23 (1 and 2): 43-48.

Panda, N., Mahapatra, A. and Sahoo, N. (1971). Field evaluation of some brinjal varieties for resistance to shoot and fruit borer Leucinodes orbonalis Guen. Indian J. agric. Sci. 41 (7): 597-601.

Panda, N., Mahapatra, S., Baduri, S. and Das, R.C. (1975). Effect of chelating agents on the resistance of brinjal plants to Leucinodes orbonalis Guen. South Indian Hort. 23 (3 & 4): 141-144.

Pal, A.B., Srinivasan, K., Veni, A. (1983). Development of breeding lines of muskmelon for resistance to fruit fly. Prog. Horti. 15(1/2):100-104.

*Pathak, M.D. and Dale, D. (1983). The biochemical basis of resistance in host plants to insect pests. Review paper presented in the international conference CHEMRAWN 11: 129-142.

Prokopy, R.J. and Koyama, J. (1982). Oviposition site partitioning in Dacus cucurbitae. Entomol. Exp. Appl. 31: 428-432.

Ranganna, S. (1978). Manual of Analysis of forest and vegetable products. Tata Mc Graw Hill Publishing Company, New Delhi. 69-71.

*Renwick, J.A.A. (1983). Non-preference mechanisms - Plant characteristics influencing insect behaviour. Proceedings of symposium of 183rd meeting of the American chemical Society p. 199-213.

Rojanaridpiched, C., Gracen, V.E., Everett, H.L., Coors, J.G., Pugh, B.F., Bouthyette, P.(1984). Multiple factor resistance in Maize to European corn borer. Maydica, 29: 305-315.

*Rufener, G.K., Mannond, R.B., Cooper, R.L. and S.T.Martin, S.K.(1986). Mexican bean beetle (Coleoptera : Coccinellidae) development on resistant and susceptible soyabean lines in the laboratory and relationship in field selection. J. Econ. Entomol. 79: 1354-1356.

Salifu, A.B., Hodgson, C.J. and Singh, S.R. (1988). Mechanism of resistance in cow pea (Vigna unguiculata (L) Walp.) genotype T.V.x 3236 to Bean Flower Thrips Megalurothrips sjostedti (Trybom.) (Thysanoptera : Thripidae) 1. Ovipositional Non-preference Tropical Pest Management 32: 180-184.

________________ Singh, S.R. and Hodgson (1988). Mechanism of resistance in cow pea (Vigna unguiculata (L) Walp.) genotype TV x 3236 to Bean Flower thrips Megalurothrips sjostedti (Trybom) (Thysanoptera : Thripidae) 2. Non preference and antibiosis. Tropical Pest Management 34: 185-188.

*Sambandam, C.N., Natarajan, K. and Chelliah, S. (1976). Studies on the mechanisms of resistance found in egg plants and certain wild solanum species to Epilachna vignctioctopunctata F. Annamalai Univ. Agr. Res. Ann.6: 53-70.

Sambandam, C.N. and Chelliah, S. (1970). Evaluation of certain solanum species for resistance to Aphis gossypii G. Indian J. Entomol 32: 271-71

Sambandam, C.N. and Chelliah, S. (1972). Final report on the scheme for the evaluation of contaloupe and musk melon varieties for resistance to the fruit fly Dacus cucurbitae Coq. U.S.D.A. PL-480 Research Project Annamalai Univ. pp.67.

Sekhon, S.S. and Sajjan, S.S.(1987). Antibiosis in maize (Zea mays L.) to maize borer chilo partellus (Swinhoe) (Pyralidae: Lepidoptera) in India. Tropical pest management 33 (1): 55-60.

Seo, S.T. and Tang, E.S.(1983). Hawaiian fruit flies (Diptera: Tephritidae) toxicity of benzyl - isothiocyanate against eggs of 1st instar of three species. J. econ. Entomol. 75(6): 1132-1135.

Seo, S.T., Tang, C.S., Sanidad, S. and Takenaka, T.H. (1983). Hawaiian fruit flies (Diptera: Tephritidae) variation of index of infection with benzyl - isothiocynate concentration and colour of maturing papaya. J. econ. Entomol. 76 (3): 535-538.

Shivarkar, D.T. and Dumbre, R.B.(1985). Binomics and chemical control of Melon fly. J. Maharashtra Agric. University 10 (3): 298-300.

Singh, R.P. and Srivastava, B.G. (1983). Alcohol extract of neem (Azadirachta indica). Seed oil as oviposition deterent of Dacus cucurbitae Coq. Indian J. Entomol. 45 (4): 497-498.

Singh, P., Bakhetia, D.R.C. and Sindhu, H.S. (1987). Plant apparancy and chemical defences in brasicas against the leaf miner Chromatiomyia horticola (Diptera: Agromyzidae) Abstracts of First symposium on crop improvement India

Singh, B.U. and Raman (1984). Influences of varietal resistance on oviposition and larval development of stalk borer (Chilo partelus (Swin.) and its relationship to field resistance in sorghum. Insect. Sci. and appli. 5: 287-296.

Singh, R. (1988). Bases of resistance in okra (Abelmoschus exculentus) to Amrasca biguttula biguttula Indian J. Agrl. Sci. 58: 15-19.

Singh, S.P. and Jotwani, M.G. (1980). Mechanisms of resistance in sorghum to shoot fly. 1. Ovipositional - Non-preference. Indian J. Entomol 42: 240-247.

Sithanantham, S., Umaid Singh, Reed, W. and Jambunathan, R. (1983). Differences of some chemical constituents of Pigeon Pea Pod Walls in relation to Pod fly susceptibility. International Piegeon Pea News letter 2: 68-69.

Smith, R.L., Wilson, R.L. and Wilson, F.D. (1975). Resistance of cotton plant hairs to mobility of first instar larvae of the pink boll worm Ibid 68: 679-683.

Srivastava, B.G., Pant, N.C. and Chaudhry, H.S. (1978). Carbohydrate requirement of Dacus cucurbitae maggots under aseptic conditions. Indian J. Entomol. 40: 150-155.

*Stipanovic, R.D. (1983). Function and chemistry of plant trichomes and glands in insect resistance. Protective chemicals in plants epidermal glands and appendages. Proceedings of symposium of 183rd American chemical society, p.69-100.

Subbaratnam, G.V. (1982). Studies on the internal characters of shoot and fruit of Brinjal governing resistance to shoot and fruit borer, Leucinodes orbonalis Guen. South Indian Hort. **30** (4): 217-220.

Subbaratnam, G.V., Butani, D.K. and Krishna Murthi Rao, B.H. (1983). Leaf characters of brinjal governing resistance to Jassid Amrasca biguttula biguttula Indian J. Entomol. **45**: 171-173.

Suharsono and Talekar, N.S. (1985/86). Preliminary studies of antibiosis factor of some soyabean cultivators to Riptortus clavatus. Agrinta **8** and **9** (2-1): 14-16.

Teli, V.S. and Dalya (1972). Studies on varietal resistance in Okra (Abelmoschus esculentus) (Lin).Mornch.) to the shoot and fruit borer. Earias vitella (Fabricius) South Indian Hort. **29**: 54-60.

Thirumurthi, S. (1970). Further studies on sorghum resistance to the shoot fly Atherigona variasoccata C. M.Sc.(Ag) Dissertation, Univ. Madras.

Thurston, R. and Webster, J.A. (1966). Toxicity of Nicotiana gossei Domin to Myzus persicae (F.) Entomol. exp. appl. **9**: 428-432.

*Thorsteinson, A.J. (1960). Host selection in phytophagous insects. A. Rev. Entomol. 5: 193-218.

Ukwungwu, M.N. (1985). Effects of silica content of rice plants on the damage caused by larvae of Chilo zacconius (Lepidoptera : Pyralidae) Bulletin Technique de I'ADRAO 5 (1): 21-22.

*Ukwungwa, M.N. and Obefiyi, J.A. (1987). Larval survival and development of the rice stem borer Chilo zacconius Bleszynski. Tropi. Agric. 64 (65-67).

Uthamaswamy, S., Jayaraj, S. and Subramanian, T.K.(1971). Biochemical mechanisms of resistance in Bhindi (Abelmoschus esculentus L.) to the leaf hopper Amrasca devastans D. South Indian Hort. 19: 53-59.

Uthamaswamy, S. (1980). Studies on host resistance in certain okra varieties to leaf hopper Amrasca biguttula biguttula (Abstract) Pesticides 14 (8): 39.

Verma, T.S., Bhag chandani, P.M., Narendra Singh, Lal, O.P. (1981). Screening of cabbage germplasm collections for resistance to Brevicoryne brassicae and Pieris brassicae. Indian J. Agri. Sci. 51: 302-305.

* Originals not seen

HOST RESISTANCE IN BITTERGOURD (*Momordica charantia* L.) TO THE INFESTATION BY THE FRUIT FLY *Dacus cucurbitae* Coq.

By

V. PADMANABHAN

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1989

ABSTRACT

In studies on the host resistance in bittergourd *Momordica charantia* L. to the infestation by the fruit fly *Dacus cucurbitae* Coq. (Tephritidae : Diptera) germplasm materials were screened to identify the sources of resistance. Sixty six accessions of bittergourd were screened in the field during the summer season, 1984-85 and based on the levels of fruit infestation by the pest in the trial, the accessions were classified into highly susceptible, moderately susceptible and moderately resistant groups.

Twenty accessions which recorded less than 25 per cent fruit infestation in the summer season trial and the accession MC 132 as the susceptible check were further screened in the field during the kharif season of 1985-86. More or less similar trends were observed in both the screening trials with regard to the levels of fruit infestation in different accessions.

Six accessions, three from the moderately resistant group (MC 103, MC 104, MC 114) two from the moderately susceptible group (MC 97, MC 123) and one from the highly susceptible group (MC 132) were selected for detailed investigations.

In the moderately resistant types the infestation by the pest occurred for a relatively shorter duration than in the susceptible ones.

In the studies on orientational response and ovipositional preference it was revealed that the adults of fruit fly had a positive attraction and marked ovipositional preference to the fruits of the highly susceptible MC 132.

In studies on the antibiosis factor of resistance it was found that the fruits of the moderately resistant accessions gave rise to larvae and pupae of larger durations and lower survival rate & adults of reduced longevity, fecundity and female/male ratio.

The fruits of the moderately resistant accessions contained lower quantities of total sugars, crude proteins, total ash and moisture and higher quantities of total phenolics and silica as compared to the fruits of highly susceptible accssion MC 132. There was significant positive correlation between the crude protein contents and ash/silica ratio on the one hand and the mean percentage of fruit infestation on the other.